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Let's make a difference at CSD 9!

Klaus Toepfer,
United Nations Under-Secretary-General and
Executive Director, UNEP

While energy is at the heart of economic and social development, its production, transportation and use are the cause of a wide range of major environmental problems at the local, national and global levels. UNEP is actively addressing these issues through the UNEP Collaborating Centre on Energy and the Environment (UCCEE).

The demand for energy, mostly met with fossil fuels (particularly oil and coal), has increased steadily during recent years, with an average growth in demand of roughly 2% per year in the 1990s. Demand is expected to continue growing, especially in developing countries, as access to energy plays a critical role in alleviating poverty through rural job creation, education, improved health and living conditions.

The energy systems developed so far to meet this demand are clearly unsustainable, as they lead directly or indirectly to health-damaging levels of air pollution, acidification of ecosystems, land and water contamination, loss of biodiversity, and global warming.

Nevertheless, there are reasons to hope that the destructive link between energy use and environmental quality can be broken. Improvements in technology, and the willingness of governments to experiment with new economic approaches to energy pricing, are fundamentally changing energy markets and presenting new opportunities. It is increasingly true that there are no technical, financial or economic reasons why the nations of the world cannot enjoy the benefits of a high level of energy services *and* a better environment.

Renewable energy technologies, clean and efficient use of fossil fuels, have in many ways come of age. These will give developing countries in particular an excellent opportunity to bypass the polluting energy path of developed countries.

Clearly we must eventually shift to sustainable energy systems. How soon that shift occurs depends on actions taken today. In the next two decades, an estimated US$ 10-15 trillion will be invested in new long-lived energy sector projects. If this investment is directed towards clean energy technologies, we will all enjoy a global economy that is more secure, more robust and much cleaner.

This issue of the Industry and Environment review, prepared by UNEP as a contribution to the discussions for the 9th session of the Commission on Sustainable Development (CSD 9), addresses the broad issues of energy and sustainable development. I trust that it will give reasons for optimism, as well as some ideas concerning practical actions that can be taken to bring about a clean energy future. UNEP stands ready to make a strengthened contribution with regard to that goal. ◆

Irene Freudenschuss-Reichl and
Mohammad Reza Salamat,
Co-Chairs of the Ad-Hoc Open-Ended Intergovernmental Group of Experts on Energy and Sustainable Development, Commission on Sustainable Development

The recently drafted report of the Secretary-General of the UN presents a very appropriate political framework for deliberations (at the second session of the Ad-Hoc Open-Ended Intergovernmental Group of Experts on Energy and Sustainable Development in late February 2001) on energy for sustainable development issues. The World Energy Assessment (WEA), jointly undertaken by UNDP, UN-DESA and WEC, provides scientific and technical grounds for informed discussions on this issue.

As clearly demonstrated by the Secretary General's Report, as well as the WEA, appropriate energy policy interventions can promote economic development, alleviate poverty, promote the status of women, improve local and indoor air quality, address regional problems such as acidification, and protect the global climate.

As for developing countries, these policy interventions need to be supported through regional and international cooperation, in order to improve the access of developing nations to financial resources and sustainable energy technologies. In our view, these are quite attainable objectives provided a political will exists.

The 9th session of the Commission on Sustainable Development (CSD 9) should catalyze this political will. Our hope is that governments will agree at CSD 9 on certain principles, and shared goals/recommendations, concerning activities to be implemented at local, regional and international levels in such areas as energy saving and efficiency, renewable energies, advanced fossil fuel technologies, and energies for rural areas.

Governments could - and hopefully will - look into framework conditions for promoting an enabling environment for attracting private as well as public investment in the energy sector, and increase regional and international cooperation. We also hope CSD 9 will result in a more coordinated UN system approach to sustainable energy. A satisfactory outcome to the discussions of the Ad-Hoc Group of Experts on Energy, along the above lines, could ensure that CSD 9 would contribute to a sustainable energy future for all.

In the light of its considerable experience concerning sustainable energy activities, we hope UNEP will continue to play its key role regarding UN system-wide goals, both in terms of inter-agency cooperation and in the field, where the Cleaner Production Centres that UNEP runs with UNIDO have already made a difference in many countries.

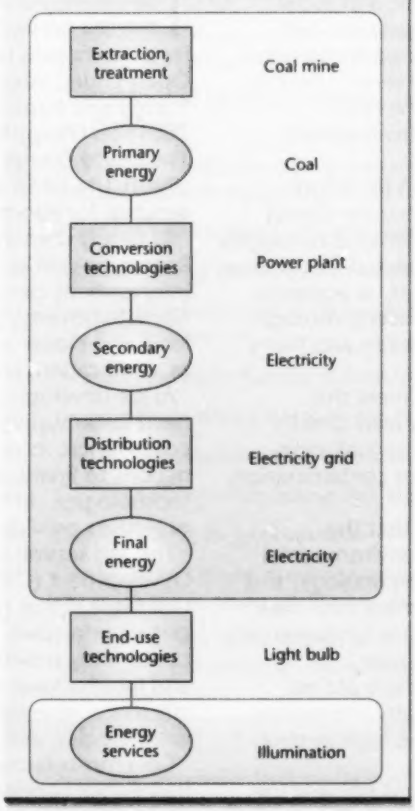
We are heartened by the wealth of intersessional activities, ranging from regional meetings to multi-stakeholder dialogues, including the Global Forum on Sustainable Energy (GFSE), whose first meeting was held in Austria in December 2000. ◆

Energy: facts and figures

Energy is closely linked to economic development and to environmental quality. It is central to the world economy, providing the power needed for industrial production, transportation and (increasingly) agriculture.

Energy is a major contributor to health, well-being and productivity, making possible the existence of services that include heating, lighting and refrigeration. The energy chain delivering these services starts with the collection or extraction of a primary energy source – for example, coal – which may be transformed into another form of energy such as electricity, transported or transmitted to the point of use, and finally used to power a piece of equipment such as a heater, lamp or motor. **Figure 1** shows an energy chain, using coal as an example.

Figure 1
Energy chain: from extraction to energy services



Energy production

Primary energy sources include fossil fuels (coal, oil, natural gas) and renewable sources such as biomass (wood, other plant sources, dung), hydropower, solar power, wind power, tidal power and geothermal energy. A small but significant proportion of the world's electrical energy is also provided by nuclear power. The ways in which these primary sources are extracted, transformed, delivered and used have enormous environmental impacts at local and global levels. They also have both positive and negative effects on human health.

Figure 2 shows global primary energy sources and totals. Between 1973 and 1997, the total amount of primary energy used in energy production increased by almost 60%. Nuclear power plants, which were almost nonexistent in 1973, provided over 6% of world energy by 1997.

A large proportion of primary energy is used for electric power generation, especially in the developed world. The share of fossil fuels, renewable sources and nuclear power in electricity generation is shown in **Table 1**. Estimates of future energy use are based on "business as usual" scenarios, in which current trends continue.[1]

There are immense differences in the primary energy resources of different countries and regions (**Figure 3**), as well as in the way these resources are used (**Figure 4**) – for example, whether they are transformed into secondary energy or consumed directly to provide heat and cooking.[2] Although less primary energy is used overall for transportation than for power generation, transportation is the most important oil-consuming sector.[3]

In Africa traditional biomass energy sources provide roughly 37% of total energy used, with commercial sources providing the remainder. However, there are huge variations among the different parts of Africa: biomass sources account for some 84% of all energy use in East Africa and the islands of the Indian Ocean, but only about 3% of that in North Africa.

In Europe and Central Asia there has been a transformation of the energy industries since the 1960s, when coal was the primary source of energy for electricity generation, industry and domestic heating in most parts of these regions. In Western Europe oil, natural gas and nuclear power are now the primary sources for energy production, while Central and Eastern Europe and Central Asian countries have reduced their coal use and moved increasingly towards oil, natural gas and hydro and nuclear power for electricity generation.

Two of Asia's giant economies, China and India, rely heavily on coal and will continue to do so in the next few decades due to its abundance and easy availability. West Asia (Iran, Iraq, Syria and the Arabian Peninsula) relies on its abundant oil and gas reserves for virtually all of its energy needs.

Primary energy sources in Latin America and the Caribbean countries vary widely. Mexico and Venezuela, which have important oil and gas resources, use them for much of their energy; in Central America over 50% and, in Brazil, some 70% of electricity is generated by hydro power. Drought in recent years has made hydro power supplies uncertain in some areas. And there is a trend in Argentina, Brazil and Colombia, for example, to move *from* renewable energy *to* fossil fuels in both the electric power and transportation sectors following deregulation of the energy sector.

North America has enormous coal, oil, natural gas and hydro resources. Coal is used to produce some 40% of its electricity. Its well developed transportation sector, and the high rate of vehicle ownership, make North America a major oil consumer as well. The United States is the world's largest oil importer, but also the second largest oil producer after Saudi Arabia.

Energy consumption trends and projections

Global energy use has climbed steadily over the years, as the industrial economies have expanded and developing countries have experienced industrialization and income growth. There are wide

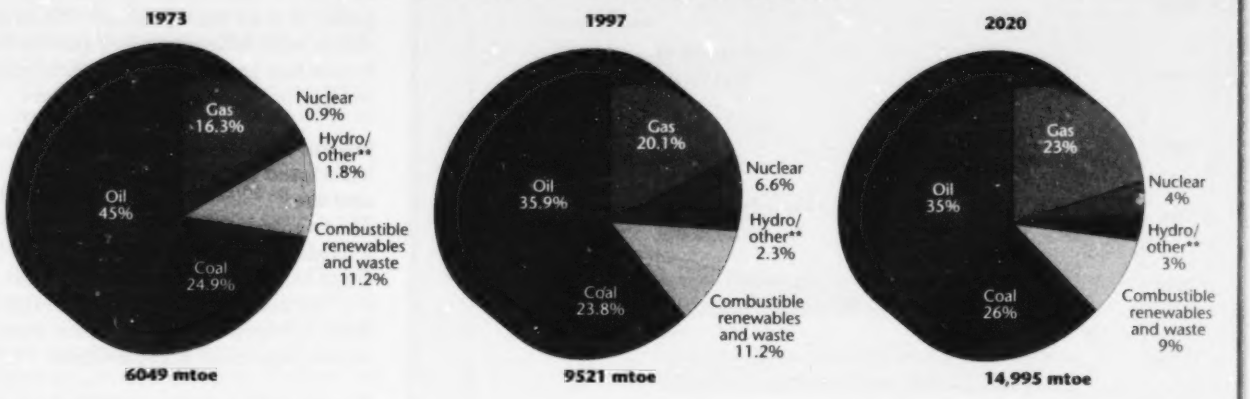
Table 1
World electricity generation

	1971	1995	2010	2020	Share of total, %* 1995	2020
Electricity generation (TWh)	5248	13,204	20,852	27,326		
Solid fuels	2131	5077	7690	10,490	38	38
Oil	1100	1315	1663	1941	10	7
Gas	691	1932	5063	8243	14	30
Nuclear	111	2332	2568	2317	18	8
Hydro	1209	2498	3445	4096	19	15
Other renewables	5	49	154	239	0.4	0.9

*Numbers do not total 100 due to rounding

Source: IEA 1998

Figure 2
Fuel shares of world total primary energy supply*



* Excludes international marine bunkers and electricity trade
** Other includes geothermal, solar, wind, etc.

Source: IEA 1998/2000

disparities in energy consumption levels, however, both within and between countries. The high-income countries, with about 20% of global population, account for about 60% of commercial energy use while nearly one-third of the world's 6 billion people do not have access to modern energy services. **Figure 5** shows the evolution of annual per capita consumption of commercial energy in the world's regions. **Table 2** shows growth in both absolute and per capita consumption worldwide. North Americans still use more energy and resources per capita than people anywhere else.

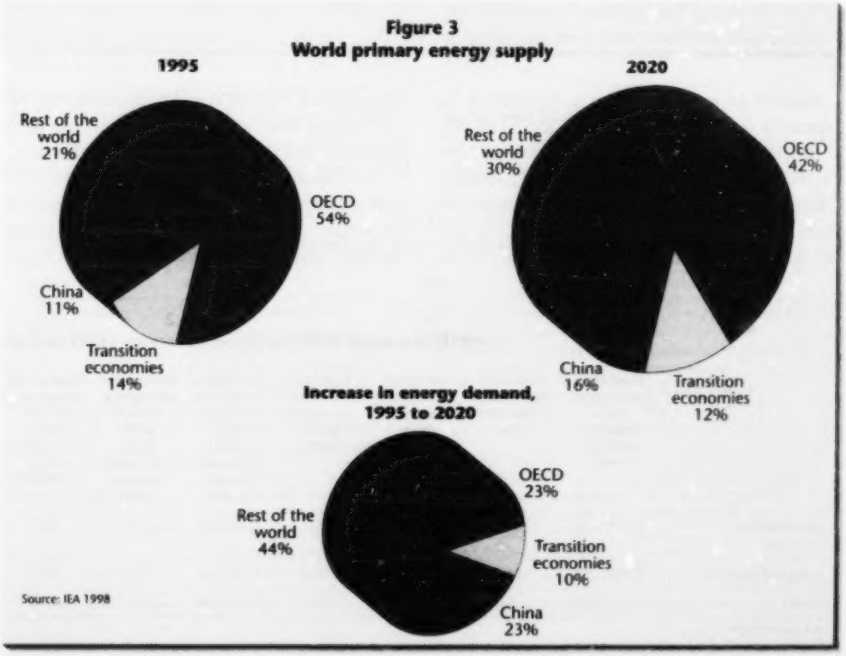
Despite continued growth in total world energy consumption, developing countries experienced a 2.3% decrease in the past year, related to the economic slowdown in East and Southeast Asia. The long-term trend is nevertheless towards greater total and per capita energy use. OECD countries' consumption grew in the past year, maintaining the trend of the last decade.[4] The general trend in OECD countries is towards a decline in energy consumption per unit of GDP. These industrialized countries are generally becoming less energy intensive, as services represent a larger share of their economies than manufacturing. In developing countries, the opposite is true, as manufacturing is edging out agriculture.

Commercial energy is only part of the story. Traditional fuels from biomass sources – firewood, agricultural residues, animal waste, charcoal and other derived fuels – still provide 20-80% of primary energy in the developing world (**Figure 6**) and are mostly not counted in commercial energy figures. In the OECD, the Transition Economies and the Middle East, the share of biomass is much lower, averaging 2-3% of total final energy consumption. As most of the biomass is non-marketed and used in a traditional manner, it is extremely difficult to collect reliable biomass energy data. The International Energy Agency (IEA) estimates that biomass energy currently represents approximately 14% of world final energy consumption, a higher share than that of coal (12%) and comparable to those of gas (15%) or electricity (14%).[5]

Demand for wood continues to increase, although it is not easy to estimate the proportion of wood harvested that is used for energy. World production of wood products, including fuelwood and charcoal as well as commercial timber products, is some 36% higher than in 1970. Wood remains the main and often only source of energy for many people in large areas of the developing world. In Africa, 90% of the population depends on firewood and other biomass for energy. Production and consumption of firewood and charcoal doubled between 1970 and 1994; it is expected to increase another 5% by 2010. Demand has risen in part because subsidies on energy alternatives have been reduced as an element of economic reform in many countries.[6] Increased firewood consumption is linked to deforestation and desertification, which are discussed below.

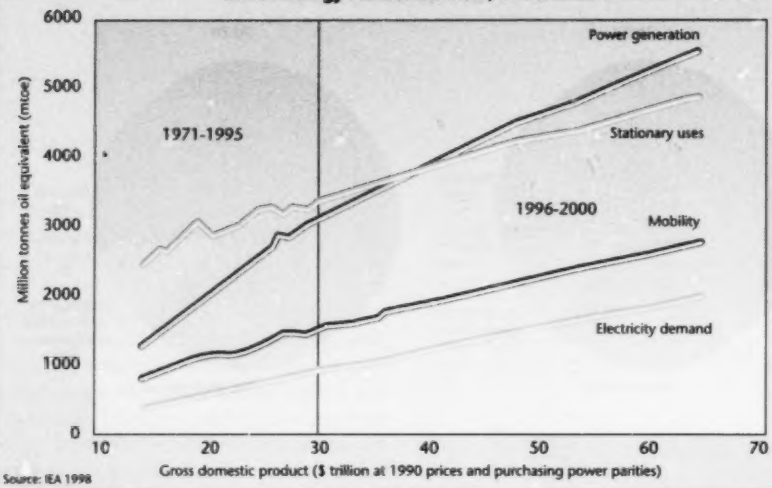
According to one IEA model, total energy use could increase by about 40% between 1993 and 2010. Developing countries are expected to increase their share of world energy use to almost 40% by 2010 and 45% by 2020.[7] This increase will reflect rapid economic expansion, high population growth, and substitution of fossil fuels for traditional biomass fuels. Growth in energy use will be especially dramatic in China (Figure 3). Energy demand is increasing more rapidly in Asia and the Pacific than any other part of the world. In 1995, for example, per capita energy consumption in the Republic of Korea equalled that of Italy. China's total carbon emissions now exceed those of the European Union, even if its per capita emissions are much lower. Demand for primary energy in Asia is expected to double every 12 years, compared with the worldwide average of every 28 years.

Figure 3
World primary energy supply



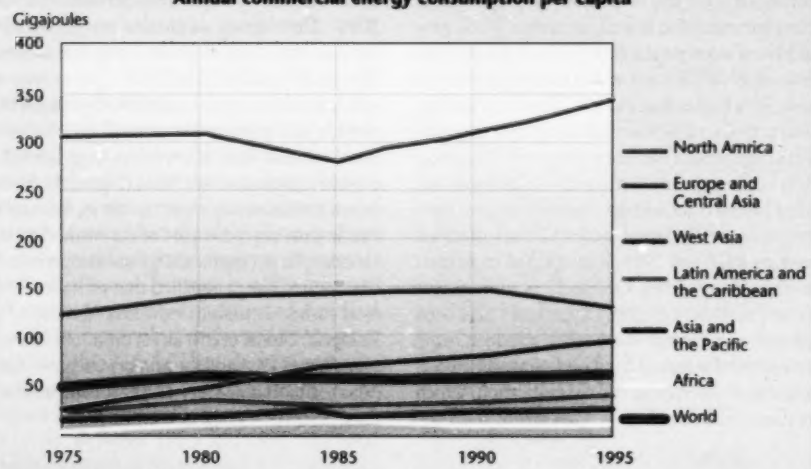
Source: IEA 1998

Figure 4
World energy-related services, 1971-2020



Source: IEA 1998

Figure 5
Annual commercial energy consumption per capita



Source: Compiled by UNEP GRID Geneva from WRI, UNEP, UNDP and WB 1998

Growth in vehicle density is expected to be especially strong in China, India and Thailand, countries where it is still relatively low but per capita income and consumption are increasing. Globally, transportation-related energy use is predicted to increase about 50% between 1993 and 2010, an average annual increase of over 2%. By comparison, transportation-related energy use will expand twice as fast in the developing world as a whole and three times as fast in South Asia.

It is difficult to predict future energy production and use with confidence, as even slight changes in important trends – population growth, energy intensity and climate change – could have important effects. Aggressive steps to reduce energy use could change the course of energy growth trends. If the Kyoto Protocol (which requires limits to the growth of, or absolute reductions in, carbon emissions in industrialized countries) comes into force, it could have profound effects on the magnitude and types of energy use in these countries.[8]

Environmental and health effects associated with energy production and use

The environmental impacts of energy production and consumption occur at every level, from individual households to the planet. Air, water, the soil/land and living organisms are all affected. **Table 3** presents examples of impacts from two major energy-related industrial sectors.

Air pollution

Energy-related air pollution is caused by the combustion of fossil fuels in vehicles, industrial boilers and furnaces, and electrical power plants. Burning of biomass fuels for charcoal production (and directly for household use) results in local and indoor air pollution. Air pollution is the primary cause of energy-related effects on human health.

The major air pollutants created by the burning of fossil fuels are CO_2, other carbon compounds including methane (CH_4), and carbon monoxide (CO), sulphur dioxide (SO_2) and nitrogen oxides (NO_x) (**Table 4**). Coal combustion produces other compounds and heavy metals as well, depending on the type and quality of coal and the types of pollution control being used. CO_2, the most important greenhouse gas, is by far the largest in terms of quantity. Total CO_2 emissions since 1950 are shown in **Figure 7**.

Coal, high-sulphur oil, and diesel fuel are the major sources of SO_2, which has serious environmental impacts in many parts of the world. Because this gas is usually found in association with particulate pollution, and as SO_2 is the precursor of fine sulphate particles, separating the health effects of these two pollutants is difficult. Together, SO_2 and particulates make up a major portion of the airborne pollutant load in many cities. They have both individual and synergistic health impacts. **Table 5** shows SO_2 emissions trends for selected regions. Although ambient concentrations of SO_2 have declined in many cities in Western Europe and North America, they remain higher (often by a factor of 5 to 10) in a number of

Table 2
Growth in energy consumption between 1980 and the mid 1990s

	Electricity consumption total (millions of kWh) 1995	Electricity consumption (1980=100) 1995	Electricity consumption per capita (kWh) 1980	Electricity consumption per capita (kWh) 1995	Commercial energy use (oil equivalent total, 1000 metric tonnes) 1980	Commercial energy use (oil equivalent total 1000 metric tonnes) 1994	Commercial energy use (oil equivalent) per capita (kg) 1980	Commercial energy use (oil equivalent) per capita (kg) 1994	Commercial energy use (oil equivalent) GDP output per kg (US$) 1980	Commercial energy use (oil equivalent) GDP output per kg (US$) 1994	Net commercial energy imports (as % of energy consumption) 1980	Net commercial energy imports (as % of energy consumption) 1994
All developing countries	3,574,530	283.6	387	815	1,280,811	2,449,513	393	568	1.69196	1.544388	-93.61	-46.54
Industrial countries	9,300,133	146.6	6601	7542	4,919,887	5,467,912	4587	4452	2.342994	2.827941	24.28	19.01
World	12,874,663	174	1566	2292	6,200,698	7,917,425	1431	1429	2.199871	2.426827	-0.07	-1.27

Source: UNDP 2000

cities in Eastern Europe, Asia and South America, where residential or industrial coal use and diesel vehicle fuel are prevalent.[9] Japan has reduced its sulphur emissions through gains in efficiency, greater reliance on oil and nuclear power, and stringent pollution control laws.

SO_2 is one source of acid deposition, which remains a widespread problem. Critical loads (the threshold at which acid deposition causes damage) are frequently exceeded over large parts of North America, Europe and Southeast Asia.

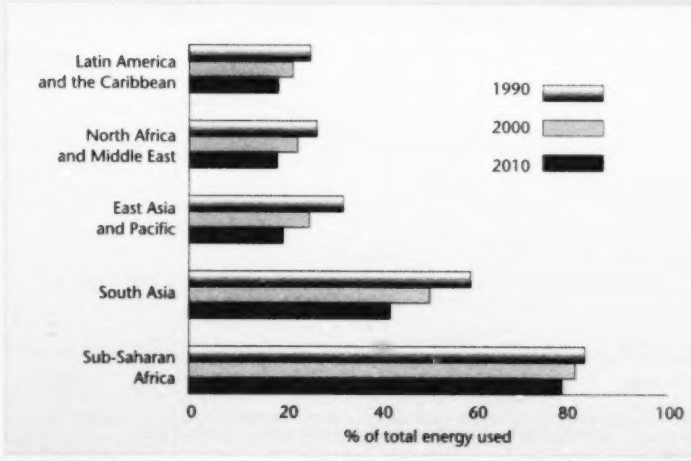
Suspended particulate matter, a complex mixture of small and large particles of varying origins and chemical composition, is an almost universal urban pollutant since it is a by-product of both fossil fuel (especially coal) and biomass burning. Coal-fired power plants and vehicle exhaust are the main sources of smaller particles: those less than 2.5 microns in diameter. These particles include fine sulphate and nitrate aerosols that form when SO_2 and nitrogen oxides condense in the atmosphere. They may contain a number of other chemicals or metals. Particulate levels in North America and Western Europe have declined greatly in recent decades due to the shift to other fuels and to cleaner technologies. They now rarely exceed 50 micrograms of particulate matter per cubic metre (µg/m³) of air. Particulate levels in some Central and Eastern European cities, and in many developing countries, are much higher, often exceeding 100 µg/m³.

The health effects of these particles are strongly linked to their size. Small particles present the severest health threat, as they can be inhaled deeply into the lungs, settling in areas where the body's natural clearance mechanisms cannot remove them, and they tend to have more chemically active and acidic constituents that cause greater damage than in the case of large particles.[10] The regulatory focus in many developed countries has shifted from larger- to smaller-sized particles, which are more difficult (and hence costly) to control.

Local impacts of fossil fuel use are heaviest in urban areas. There are marked regional differences in the type and severity of air pollution, but urban air pollution problems have reached crisis proportions in many cities in the developing world (see, for example, *Industry and Environment* Vol. 23, No.1-2). Vehicles in these cities are often old and use leaded fuel, while manufacturing, mining and industrial activities, and power stations, are increasingly important sources of emissions. The Asia and Pacific region has experienced significant growth in atmospheric pollution from heavy use of coal and high sulphur fuels, as well as from traffic growth. Burning of biomass is another problem in Africa and Asia: in tropical and sub-tropical areas, urban air pollution is exacerbated by high temperatures and levels of sunlight, which promote formation of photochemical oxidants.

Increasing coal use and a rapidly expanding fleet of cars and trucks worldwide are the two most serious threats to air quality as fossil fuel consumption rises. Greater fossil fuel use is likely to lead to an increase in air pollution levels, particularly in urban areas. Rapid urbanization in the developing world will expose greater numbers of people to polluted urban air. Without improved pollution control, some cities in developing countries could see air pollution levels double by 2010.[11]

Figure 6
Current and projected use of biomass for energy



Source: WRI 1998 from World Bank 1996

Strenuous efforts to abate atmospheric pollution in the industrialized countries have begun. Implementation of the Convention on Long-Range Transboundary Air Pollution has resulted in significant reductions in emissions of acidifying gases in Europe and North America. For example, SO_2 emissions in Western, Central and Eastern Europe fell by 50% between 1985 and 1994 in line with the Convention's protocols. Significant problems remain, however, despite these improvements. GEO-2000 found that critical loads for acid deposition are still being exceeded in more than 25% of ecosystems in Western and Central Europe. NO_x emissions in North America increased by about 10% between the 1980s and 1990s. These problems are likely to become worse, rather than better, as the economies of Eastern Europe and Central Asia grow stronger and car use increases not only in these regions, but also in the rest of Europe and in North America.

On the positive side, many countries in Latin America and the Caribbean have substantial potential to reduce their contributions to the build-up of greenhouse gases given this region's renewable energy sources.

In all regions, future levels of atmospheric pollution will be determined largely by the use of energy from fossil fuels. The Intergovernmental Panel on Climate Change (IPCC) has predicted that global economic output could double between now and 2050, with energy demand reaching nearly three times that in 1990. If the developing countries followed the conventional development path, there would be a massive increase in emissions of atmospheric pollutants. However, this need not be the case – as has been proved in some industrialized countries. For example, sulphur emissions in Europe peaked in the 1970s and then steadily declined, despite increasing energy consumption. Similarly, the implementation mechanisms developed for the Kyoto Protocol are intended to help developing countries restrict their emissions of greenhouse gases.[12]

Indoor air quality

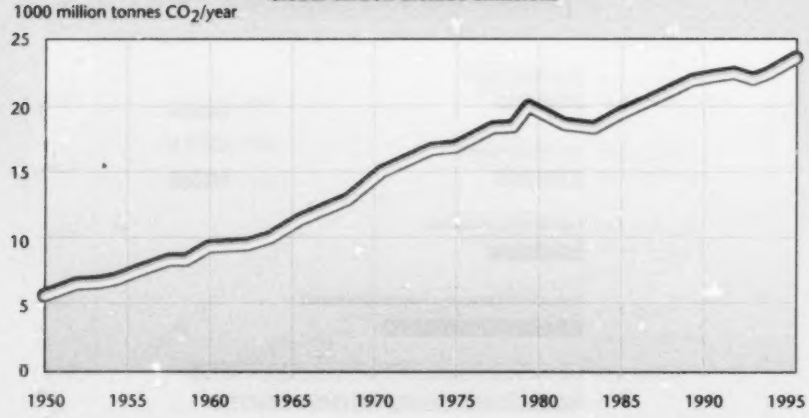
By far the greatest source of indoor pollution is the use of traditional cooking and heating fuels in

Table 3
Environmental impacts of major industries (some examples)

Sector	Air	Water	Soil/land
Coal mining and production	• Emissions of dust from extraction, storage, and transport of coal • Emissions of CO and SO_2 from burning slag heaps • CH_4 emissions from underground formations • Risk of explosions and fires	• Contamination of surface water and groundwater by highly saline or acidic mine water	• Major surface disturbance and erosion • Subsidence of ground above mines • Land degradation by large slag heaps
Refineries, petroleum products	• Emissions of SO_2, NO_x, hydrogen sulphide, hydrocarbons, benzene, CO, CO_2, particulate matter, PAHs, mercaptans, toxic organic compounds, odours. • Risk of explosions and fires	• Use of cooling water • Emissions of hydrocarbons, mercaptans, caustics, oil, phenols, chromium, effluent from gas scrubbers	• Hazardous waste sludges from effluent treatment; spent catalysts, tars

Source: WRI 1997

Figure 7
Global carbon dioxide emissions



Global carbon dioxide emissions continue to increase. Average annual increase over the past decade has been 1.3% or nearly 300 millions tonnes a year.

Source: CDIAC 1999

Figure 8
World carbon emissions by region, 1970-2020

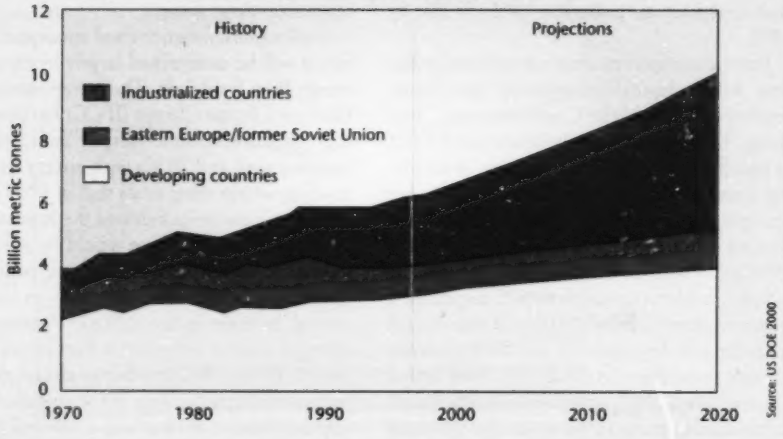


Table 4
Share of greenhouse gases in total GHG emissions in Annex I countries and the contribution of the energy sector, 1995

Gas type	CO_2	CH_4	N_2O	Others	Total
Share	82%	12%	4%	2%	100%
Contribution of energy sector	96%	35%	26%	NA	85%
Main source, energy sector	Fuel combustion	Fugitive fuel	Fuel combustion	NA	

Source: UNFCCC, "Second compilation and synthesis of second national communications," FCCC/CP/1998/11/Add. 1, September 1998

developing countries. Some 3.5 billion people, mainly in rural areas but also in many cities, rely on biomass fuels (**Figure 6**), which produce large amounts of particulate-laden smoke and other air pollutants in the confined space of the home, creating conditions for high exposures. In such conditions, exposure to pollutants is frequently much higher indoors than outdoors (**Table 6**). The health threat is so serious that the World Bank has designated indoor air pollution in developing countries as one of the four most critical global environmental problems.[13]

Greenhouse gases, climate change and the Kyoto Protocol

Carbon-containing gases and some other gases released by industrial activities can trap solar heat near the Earth's surface, creating a warming effect and potentially causing climate change worldwide. World energy use is at the centre of concerns about global climate change, with most of the attention focused on the commonest greenhouse gas by volume, carbon dioxide (CO_2). The two main anthropogenic sources of CO_2 emissions are fossil fuel combustion and land use changes, mainly deforestation. The IEA estimates that energy-related CO_2 emissions represent 70% of all greenhouse gas emissions, while non-carbon energy-related emissions represent another 10-15%.[14] Table 4 shows that energy's contribution to greenhouse gas production is even greater in the high-consumption industrialized countries. Fossil fuel combustion accounts for over 80% of anthropogenic CO_2. It also releases a significant amount of methane (NH_4), the second most important greenhouse gas by volume.

The carbon released from energy-related activities and from land-use changes appears to be the main factor in the rapid rise in atmospheric CO_2 concentrations compared to the pre-industrial period.[15] By the late 1990s, annual CO_2 emissions were almost four times their 1950 level. The atmospheric concentration of CO_2, which had been about 280 parts per million by volume (ppmv) in 1780, at the beginning of the Industrial Revolution, rose to 320 ppmv by 1965 and 367 ppmv by 1999. The atmospheric concentration of methane, about 700 parts per billion by volume (ppbv) in 1780, was about 1750 ppbv by 1999.[16] **Figures 8 and 9** show relative levels of total and per capita carbon emissions by region.

There is a growing understanding of the links between atmospheric problems such as local air pollution, acid rain, global climate change and stratospheric ozone depletion. Isolated responses to one environmental problem may in fact worsen another. For example, catalytic converters on cars decrease nitric oxide emissions and help reduce acid rain and urban smog, but they also release higher levels of nitrous oxide, a potent greenhouse gas and contributor to stratospheric ozone depletion. While sulphate aerosols in the upper atmosphere contribute to acid rain, they may offset greenhouse warming by reflecting sunlight away from the Earth's surface. Reducing sulphur emissions from power plants by switching to low-sulphur coal or using scrubbers may therefore exacerbate the problem of climate change.

There is still no definitive proof that human activities are causing global warming, but the IPCC says the balance of evidence suggests that there is indeed a discernible human influence on the global climate. Expected results include a shifting of climatic zones, changes in species composition and the productivity of ecosystems, an increase in extreme weather events, and temperature- and weather-related impacts on human health.

Through the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, efforts are underway to control and reduce greenhouse gas emissions. The parties to the Kyoto Protocol have developed a plan of action for using new international policy instruments such as the Clean Development Mechanism. However, implementation of the Kyoto Protocol alone will not be enough to stabilize CO_2 levels in the atmosphere.

Land and water impacts

Primary energy impacts on land and water are caused by oil extraction and refining, coal mining

and combustion, and dams producing hydropower. Other impacts are mainly related to use of fuel for vehicles, but they may also be caused by energy-related waste disposal, soil and water contamination by airborne pollutants, and power transmission lines.

The air pollution associated with coal has had severe effects on land and water in some regions as a result of acid rain. Acid deposition, which damages both natural and man-made surfaces, can result in acidification of lakes, leading to the loss of fish populations. It has caused extensive damage to forests in many parts of Europe and North America.

Deforestation is a secondary effect of energy use in some places, mainly in Sub-Saharan Africa. Cutting or gathering of firewood is often blamed for forest loss. However, a recent study has shown that deforestation from other activities may be the cause, rather than the effect, of local fuelwood shortages.[17]

Hydro power is often considered a "clean" form of energy, and it does have far lower impacts on air quality than fossil fuels. Its drawbacks include the effects of dams on river ecosystems, ecological changes, effects on fish and other water species, loss of scenic natural areas, and reduced water flow for other uses. A conspicuous and often controversial effect of large-scale hydro power development is population displacement. These effects can be minimized through careful site selection and project design that limits the maximum reservoir level. Many projects already built around the world, and some under development, will continue to have major impacts.

Table 5
SO_2 emissions from fossil fuel burning

	1980	1990	1995	2000	2010
			(millions of tonnes)		
Europe	59	42	31	26	18
United States	24	20	16	15	14
Asia	15	34	40	53	79

Note: per capita emissions in Asia are still many times lower than those in Europe or the United States

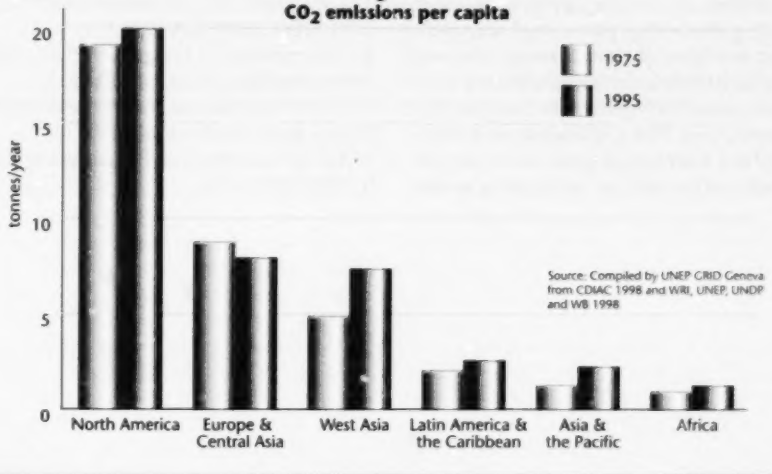
Source: Worldwatch Institute 1998

Table 6
Indoor particulate concentrations from biomass combustion in developing countries

Region	Number of studies	Duration	Micrograms per cubic metre (mg/m^3)
Pacific	2	12 h	1300-5200
South Asia	15	Cooking period	850-4400
		Cooking	630-820
		Non-cooking	880
		24 h	2000-2800
		Various	2000-6800
		Urban infants, 24 h	400-520
China	8	Various	2600-2900
		Various	1100-11000
Africa	8	Cooking/heating	800-1700
		Cooking/heating, 24 h	1,300
		Urban area, 24 h	1300-2100
			400-590
Latin America	5	Cooking/heating, 24 h	440-1100
			720-1200

Source: WRI 1998 from World Health Organization

Figure 9
CO_2 emissions per capita



Subsidies and pricing

As shown in **Figure 10**, there is a strong correlation between energy prices and energy intensity. Energy subsidies can distort energy markets and, by keeping prices artificially low, encourage energy consumption. They are often detrimental to economic and energy efficiency, environmental performance and government budgets.[18] Phasing out energy subsidies in greenhouse gas-emitting sectors is one strategy parties to the Kyoto Protocol are discussing as a means of achieving the Protocol's aims.

Energy and sustainability

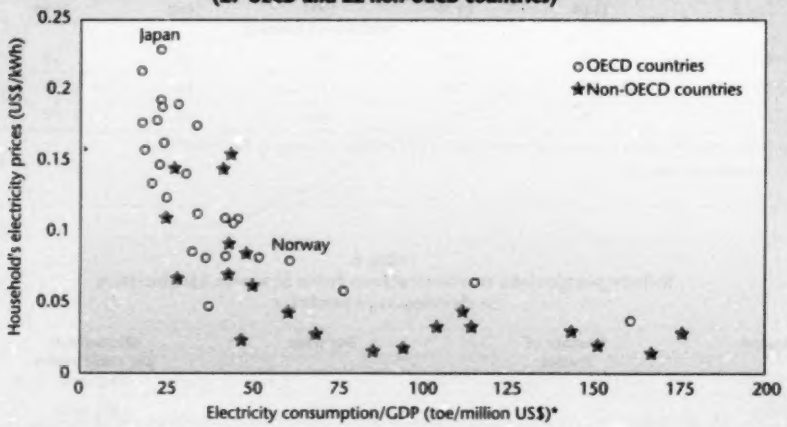
Significant growth in energy consumption in developing countries will be both essential and inevitable in the coming decades. Increasing energy use is required for economic development in these countries, and rising incomes and growing populations will in turn stimulate energy demands. Increased energy consumption in developing countries will also lead to higher emissions of greenhouse gases. It is clear that current patterns of energy production, distribution and use are unsustainable. Devising means to reduce the rate of growth of greenhouse gas emissions without impeding needed development is a major climate policy challenge.[19]

The UN Economic and Social Council (ECOSOC)[20] has identified eight key energy sustainability issues:

- Accessibility: available, reliable and affordable energy sources;
- Rural energy services that meet the basic and development needs of rural and dispersed populations;
- Financing of sector improvements needed for sustainability;
- Energy efficiency in production, conversion, distribution and use;
- Advanced technologies, including cleaner fossil fuels and improved nuclear technologies;
- Renewable energy: accelerated development and wider-scale use;
- Improved energy efficiency and mitigation of the environmental and health impacts of energy in the transport sector;
- International cooperation, including greater capacity building, investment and technology transfer.

A number of promising technologies and strategies are gaining attention as ways to satisfy the world's energy needs, especially those of developing countries, without irreparably damaging the environment. Greater use of renewable energy sources, micropower sources and energy efficien-

Figure 10
Electricity prices and electricity use per GDP, 1996
(27 OECD and 22 non-OECD countries)



* Calculated using purchasing power parities

Source: IEA 1998

cy measures can contribute to energy sustainability, although fossil fuels could not be entirely replaced for at least many decades.

Several renewable energy technologies, such as fuel cells and exploitation of solar, wind and geothermal sources, have the potential to produce energy with considerably lower impacts, notably on air quality, than fossil fuels. **Table 7** shows life-cycle air emissions projects for coal compared to a number of renewable technologies. **Table 8** summarizes land, water and solid waste impacts. Some renewable and micropower options can give the world's poor greater access to energy, even in remote areas. Decentralized energy technologies, including photovoltaic power, small-scale hydro power, new forms of biomass energy, and wind power, can stimulate development in areas where it is not economically practical to extend the electric power grid. New applications for biomass energy and water pumping can reduce the time needed to collect fuel and water, giving women time to devote to more productive tasks. Many renewable energy technologies can be produced and used at the local level, and so address the root causes of poverty by creating new employment opportunities.[21]

The articles in this issue of *Industry and Environment* describe several such possibilities, as well as addressing the broader issues of a sustainable energy future.

Notes

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3. US Department of Energy (US DOE) (2000), *International Energy Outlook 2000*, p. 1.
4. UN Committee on Energy and Natural Resources, on-line document, 2000.
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16. Carbon Dioxide Information Analysis Center (CDIAC), *Trends*, on-line document, 2000.
17. UNDP, *World Energy Assessment*, on-line document, 2000.
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19. UNDP, *Promoting Sustainable Development while Limiting Greenhouse Gases: Trends and Baselines*, on-line document, 2000.
20. UN ECOSOC (2000) *Energy and Sustainable Development: Key Issues*, p.3.
21. UNDP, *Climate Change and Sustainable Development*, on-line document, 2000. ◆

For further reading

- *Fuel for Thought: An Environmental Strategy for the Energy Sector*, World Bank, 2000.
- *International Energy Outlook*, US Department of Energy, 2000.
- *Wind Energy in the 21st Century*, UNEP Collaborating Centre on Energy and Environment, 2000.
- *World Energy Assessment*, UNDP, UN Department of Economic and Social Affairs and World Energy Council, 2000.
- *World Energy Outlook 2000*, International Energy Agency (IEA), 2000.

Table 7
Life-cycle emissions from selected generating technologies:grams emitted per kilowatt hour of output (g/kWh)

Technology / Emission	Coal		Biomass	Photovoltaic (PV)**		Wind	Geothermal***	Nuclear
	Average current system	New source performance standard	Gasification combined-cycle	Grid-tied rooftop PV	Stand-alone rooftop PV with battery		Flashed steam (reservoir emissions only)	Light water reactor
Particulates	9.21	9.78	0.04	unknown	unknown	unknown	0	0.09
SO_2	6.70	2.53	0.30	unknown	unknown	unknown	0.03	0.16
NO_x	16.1	14.6	0.69	unknown	unknown	unknown	0	0.11
CO	1.3	1.5	0.08	unknown	unknown	unknown	0	0.01
Non-methane hydrocarbons	1.0	1.3	0.60	unknown	unknown	unknown	0	unknown
CO_2 from mining or cultivation	9	8	28	NA	NA	NA	0	unknown
CO_2 from transportation	17	16	6	NA	NA	NA	0	unknown
CO_2 from power generation	996	917	12	0	0	0	45-81	unknown
Total CO_2	1022	941	46*	unknown	unknown	unknown	45-81	36.6
Methane (CH_4)	4.4	5.2	0.005	unknown	unknown	unknown	0.09-0.75	0.12
Total CO_2 equivalent	1114	1050	46	60-150	280-410	7-74	47-97	39.1

* Includes only quantity not absorbed during the biomass growth cycle.
** Figures refer to complete rooftop systems incorporating multi-crystalline silicon modules: one for grid-connected use, and one for stand-alone, battery-augmented applications.
*** All geothermal estimates include only emissions from geothermal reservoirs. Life-cycle analyses would reveal impacts greater than those included here for the sake of comparison. Note that binary geothermal plants have no reservoir emissions at all.

Source: US DOE 2000

Table 8
Land, water and solid waste impacts of various generating technologies

Technology / Resource	Photovoltaic	Wind	Geothermal	Biopower		Coal	Nuclear
	0.02 to 20 MW utility-scale, thin film	25 MW wind farm	50 MW flashed steam or binary	75 MW gasification	50 MW direct-fired	360 MW with desulphurization	1000 MW light water
Land (ha/MW)	5	20-46 (non-exclusive)	0.2 (plant) 3.2 (steam field)	0.54 (plant) + 318 (crops)	0.90 (plant) + 487 (crops)	0.69 (plant) + 218 (mining)*	0.40 + mining*
Fuel (metric tonnes/year/MW)	0	0	0	3560	5420	3140	0.03
Water (m^3/MWh)	0	0	0	0.07 (power plant)	0.81 (power plant)	1.81 (90.4)**	1.79 (112)**
Solid waste from plant (metric tonnes/year/MW)	0	0	0	269 (ash)	185 (ash)	475 (ash and sludge)	0.03 + low-level water

* Land use data assume 500 MW coal plant with on-site fuel preparation and solid waste storage. Nuclear plants with cooling ponds may occupy an additional 1.01 ha/MW. Coal mining area is an average of shaft and surface mines.
** Figures in parentheses represent non-consumptive use.

Source: USDOE 2000

The "EMPRESS" Project: achieving lasting energy savings through improved management

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Summary

The "EMPRESS" (Energy Management and Performance Related Savings Scheme) Project in Central and Eastern Europe is being sponsored by UNEP and the Global Environment Facility. This project brings together two well established energy efficiency approaches – Energy Service Companies (ESCOs) and Monitoring and Targeting (M&T) – to produce CO_2 savings through low-cost measures and improved management procedures. Implementation costs will be paid out of the resulting energy savings.

Résumé

Le projet " EMPRESS " (Gestion de l'énergie et économies liées au rendement énergétique) mis en place en Europe centrale et orientale est parrainé par le PNUE et le Fonds pour l'environnement mondial (FEM). Il entend associer deux approches éprouvées du rendement énergétique – d'une part les entreprises de services énergétiques (ESCOs), d'autre part la surveillance et la fixation d'objectifs (M&T) – pour réduire les émissions de CO_2 par des mesures peu coûteuses et de meilleures méthodes de gestion. Les coûts de mise en œuvre seront compensés par les économies d'énergie réalisées.

Resumen

El Proyecto "EMPRESS" (Energy Management and Performance Related Savings Scheme o "Plan para el ahorro energético mediante la gestión y los resultados") se desarrolla en Europa Central y Oriental, bajo los auspicios del PNUMA y de Global Environment Facility. Este proyecto tiene por objeto combinar dos enfoques de probada eficacia en materia de ahorro de energía: las Energy Service Companies (ESCOs) y el sistema Monitoring and Targeting (M&T), con miras a lograr reducciones del CO2 mediante la aplicación de medidas de bajo costo y de mejores métodos de gestión. Los costos de aplicación se sufragarán con los resultados del ahorro energético.

This article describes the "EMPRESS" Project, which is currently being sponsored by UNEP and the Global Environment Facility (GEF) in Central and Eastern Europe (C&EE). It is being undertaken by Enviros, an international energy and environmental company based in the UK with extensive experience in C&EE and other countries in transition.

"EMPRESS" stands for Energy Management and Performance Related Savings Scheme. The purpose of the project is to achieve lasting energy (and hence CO_2) savings in the industry and buildings sectors through improved management of energy usage. It is aimed primarily at identifying, implementing and maintaining savings that are often overlooked in conventional energy-saving programmes.

End-user energy efficiency projects will make a vital contribution to the reduction of carbon emissions from Central and Eastern European countries. To maximize the potential benefits of energy efficiency investments, it is important to recognize that projects generally fall into one of two broad categories:

- *Large complex projects, such as co-generation or process redesign.* These projects usually require significant levels of investment and achieve significant energy savings. Payback periods are typically in the range of three to five years.
- *Small projects related to improved control, maintenance or "housekeeping".* In most organizations there are many such small projects which could be undertaken. They are usually achievable at zero or low cost. The payback period for a "package" of such small projects is often around one year.

It is somewhat ironic that many organizations investigate the large complex projects but ignore opportunities for the more cost-effective small projects. This is often because the large projects are prestigious, and because a single project will achieve a high level of savings. The small projects are often seen as "boring" and may require substantial input of engineering effort to ensure sufficient attention to detail.

The purpose of the approach outlined in this article is to overcome the barriers that cause this to happen, and to help companies in C&EE achieve the most cost-effective savings possible.

Background

The EMPRESS Project brings together two well established energy management approaches: Energy Service Companies (ESCOs) and Monitoring and Targeting (M&T).

Energy Service Companies (ESCOs)

ESCOs have been operating in the United States and Western Europe since the mid-1980s. The concept is now fairly well understood in most countries that are seeking to reduce energy demand. Although the form of the contract varies, the fundamental idea is that the ESCO will:

- carry out an energy audit at the host site to identify savings;
- provide finance for the energy saving systems;
- install the equipment; and
- maintain the equipment and monitor savings.

The ESCO's costs and profits are recovered through a share of the savings achieved, or through some mechanism related to the pre-existing energy bill.

The advantages for the host company (or national organization) are that no up-front capital is required in order to obtain the savings, and that all the risk lies with the ESCO. If no savings are achieved, no fee is payable by the end-user. The disadvantage is that contracts tend to be of long duration (typically eight to ten years). Also, because of the risk and the difficulty of measuring savings in the rapidly changing environment typified by an average industrial site, the ESCO will normally favour a stable operating situation. For this reason, most ESCOs invest only in the buildings sector (especially the public sector) and in co-generation schemes.

In the US and some parts of Europe, ESCOs are often subsidiaries of utility companies and have frequently been associated with demand side management (DSM) programmes.

Monitoring and Targeting (MT&T)

M&T was pioneered in the UK during the 1980s. It is now increasingly used in many EU countries and elsewhere, including C&EE. M&T is based on careful interpretation of metered energy data and associated variables, such as production output or weather conditions. At its most fundamental level, weekly energy consumption for a building, process or department is *monitored* and plotted against the appropriate variables (Figure 1). The data are used to set energy usage *targets*.

and variance from a target indicates good or bad performance. Action is then prompted by management to correct situations when the target level is exceeded (**Figure 2**).

The low-cost nature of the technique makes it a highly attractive way to achieve the UN Framework Convention on Climate Change (FCCC) and GEF objectives in developing countries. M&T is also consistent with the preventive approach to reducing the environmental effects caused by manufacturing that UNEP and others call *cleaner production*.

The key aspects of M&T are as follows:

- M&T is a management technique providing "management information" about energy and utility usage. The M&T system helps staff identify and rectify areas of poor performance.
- The typical level of energy saving achieved through implementing M&T has been in the range of 5-15%. This has usually been achieved with payback periods of one year or less.
- M&T systems provide various secondary benefits, such as reduced environmental impacts and improved departmental cost data. M&T not only saves energy in its own right, but also helps support a broader energy efficiency campaign in an end-user company. It can help identify and justify large projects, monitor the progress of capital investments, and facilitate comparisons between sites in a multi-site company.
- The M&T methodology can be applied to non-energy "consumables" such as water, process gases, etc. It can also be applied to waste streams such as effluent, solid waste, toxic waste, etc.
- In the context of the EMPRESS project, the rigorous nature of M&T data will constitute an excellent platform for verifying CO_2 emission reductions.
- By monitoring at a sufficiently detailed level (through installation of sufficient sub-meters) the M&T system can clearly show the cause of poor performance (e.g. that air compressors are operating inefficiently). With appropriate training, motivation and mentoring, operating and engineering staff can identify and rectify problems based on the M&T data.
- Four areas of investment are required in order to set up and operate an M&T system. These are:
  - *Metering*. This is the largest initial cost. A sufficient number of sub-meters must be installed to measure utility use (electricity, gas, steam, water, etc.) throughout the site.
  - *M&T software*. This is required in order to analyze metered data, calculate targets and produce helpful management reports. The software needs to be available in the local language if M&T system usage is to involve a wide range of staff in the end-user organization.
  - *Technical support and staff costs*. As M&T is a management tool, it requires manpower input. Outside experts need to be involved in system specification and set-up. They also have an ongoing role in helping maximize the benefits of M&T. Site staff have an important role to play, too.
  - *Energy-saving investments*. M&T usually saves some energy without any further investment. However, some savings will be achieved by low-cost investments in equipment such as controls. Allocations need to be made for such investments.

Even though M&T has been shown to be very cost-effective, various technical and institutional barriers prevent its widespread adoption (see below). To overcome these barriers in C&EE, implementation of M&T using an ESCO approach may be beneficial. The EMPRESS project is designed to test and demonstrate this proposition.

Barriers to M&T in Central and Eastern Europe

In addition to the UK, Enviros has now implemented M&T systems at sites in the Czech Republic, Slovakia, Hungary and Romania, as well as in South America. If M&T is well established in the UK, and if the savings potential is good, what prevents its uptake in C&EE and other countries in transition? The main barriers to more widespread implementation of M&T that have emerged from this work appear to be:

- *Lack of awareness*. Outside the UK, there is relatively little awareness of M&T's potential. This is the case in the US and many EU countries, as well as in C&EE and developing countries. Any M&T initiative in C&EE will therefore need to create general awareness of this approach. The project described in the case study illustrates what can be achieved. Similar case studies need to be widely disseminated. Some C&EE countries (notably the Czech Republic and Slovakia) are promoting M&T as part of national energy-saving programmes.
- *Lack of an M&T skill base*. Although the general principles of M&T are readily understood, significant experience and skill are required to implement it effectively. Without "early successes", many M&T projects have failed. This can be avoided by setting up M&T systems correctly. An M&T initiative in C&EE needs to ensure that a good level of expert consultancy support is established locally, and that end-user companies are given adequate training.
- *Lack of confidence in the initial investments*. Initial investments in metering can be relatively modest, but there is often a great lack of confidence in the investments being worthwhile. A common question from factory management is: "How can I be certain that purchasing meters will lead to savings?" This problem is inevitable in the case of a technique like M&T. Savings are only identified after the metering is installed. Hence the initial investment is an "act of faith". While numerous case studies can be cited to prove the effectiveness of M&T, this barrier remains significant. An M&T initiative in C&EE may need to provide metering finance to overcome this barrier.
- *Lack of appropriate manpower input to the project*. Some projects fail because end-user companies fail to dedicate enough effort to the M&T system. They might also fail because insufficiently skilled staff attempt to implement M&T. An M&T initiative in C&EE will need to fund significant levels of expert support in each host company. It will also be important to ensure a good level of host company commitment, guaranteeing a reasonable host company input.
- *Lack of continuity*. M&T is an ongoing mechanism that must be established as part of a company's management culture. Many M&T systems fall into disuse because the M&T "champion" moves on to another job. It is important that projects are structured in such a way that this does not occur.

Overcoming these barriers clearly requires an innovative approach.

The EMPRESS concept

The EMPRESS concept is designed to deliver improved Energy Management through applying M&T techniques using a new type of ESCO that recovers its costs from Performance Related Energy Savings – an "M&T ESCO".

An M&T ESCO would provide end-user companies with:

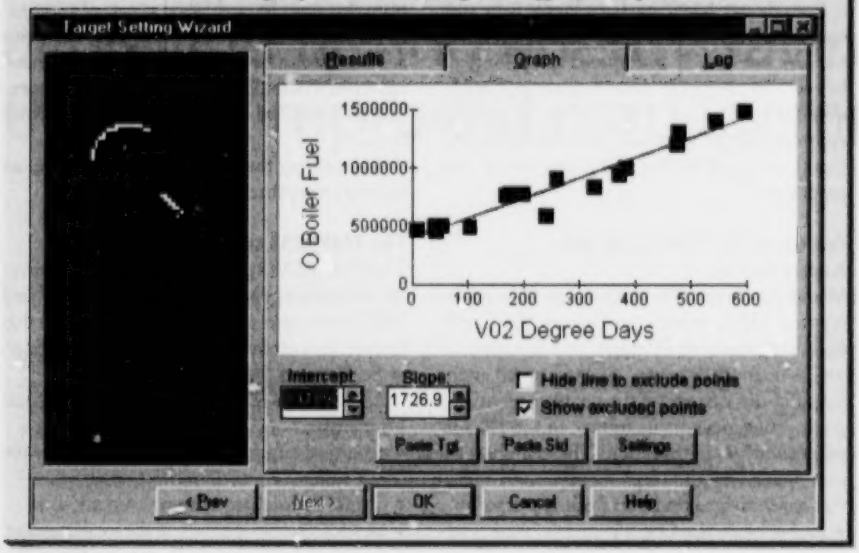
- technical support to specify and set up the M&T system;
- finance to purchase meters;
- an M&T software system in the local language;
- technical support to help operate the system and identify savings;
- training for end-user staff;
- finance to help implement low-cost energy-saving projects;
- optionally, M&T "bureau" facilities (where the M&T ESCO carries out many of the tasks normally done by the end-user's staff); and
- optionally, finance for larger, more complex projects.

Much of the initial finance for M&T efforts in individual end-user companies will come from the M&T ESCO, with repayments made on the basis of shared savings. An ESCO approach of this sort should overcome many of the barriers to M&T. In particular, it overcomes the "lack of confidence" problem and ensures that sufficient expertise is available to specify and operate the system properly.

It is important to recognize, however, that there are two critical differences between an M&T ESCO and a conventional ESCO: an M&T ESCO provides a different type of "energy service", and it provides a better route to the industrial sector.

With a conventional ESCO the emphasis is on the *equipment* installed. After installation, the ESCO focuses on maintaining the equipment and monitoring the energy savings. With an M&T ESCO, the emphasis is on *management* and *people* issues within the client company. The equipment installed (metering, data collection, and low-cost sensors and controls) is a means to an end. It enables the M&T ESCO to establish a management reporting system and to work with the client's staff to change operating methods (through training, mentoring and motivation). There is much more ongoing contact with client operational staff than in the case of a conventional ESCO. Savings are achieved without major capital expenditure, and the contracts can therefore be much shorter (say two to three years, rather than the eight to ten years typical of a conventional ESCO). The particular attractiveness of the

Figure 1
Monitoring report on a building's energy consumption



M&T approach is that it couples funds for investment with targeted information and managerial training, thereby removing multiple barriers to energy efficiency improvements in the host firms.

The long-term nature of conventional ESCO contracts is a major barrier in industrial situations, in that production processes constantly change. This makes it difficult for the ESCO to monitor savings accurately, which in turn leads to investment in more stable environments as described earlier. The majority of conventional ESCOs, in both Europe and North America, operate in what is commonly referred to as the "MUSH" market (for MUnicipalities, Schools, and Hospitals) and do relatively little work in the industrial sector.

M&T ESCOs are particularly well suited for industrial settings since:

- the contract periods are short;
- close monitoring of process and production variations is inherent in the service;
- the M&T concept is well proven in a wide range of industries.

The services provided by conventional ESCOs and M&T ESCOs should therefore be complementary, as each addresses different needs.

Once proven, the M&T ESCO service could be offered by a wide range of operators in the energy field, especially as the financial barriers to entry are low. These operators could include:

- utility companies, as part of a DSM programme;
- conventional ESCOs expanding their range of operations (and probably their profit margins!); and
- consultancies working in conjunction with local financial institutions.

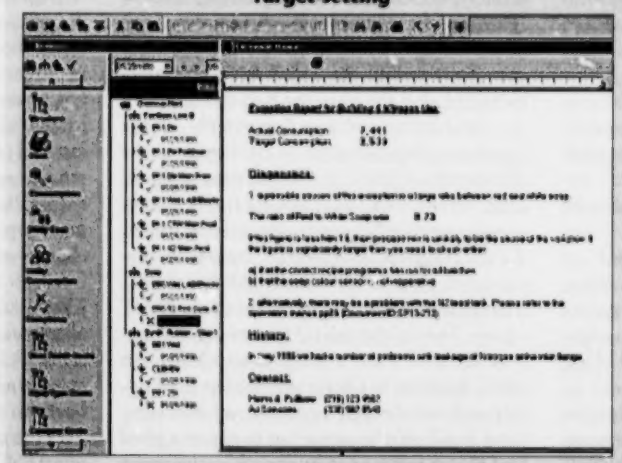
It is certainly a service that could be offered through and by industry trade associations, for example in a sectoral Voluntary Agreement (VA) on CO_2 reductions. The possibilities for long-term partnership between M&T ESCOs and industry associations are very good, since the M&T ESCO provides the specialist service and the association provides the route to the "market" and acts in an independent, supervisory role. At the same time, the association can demonstrate to government that it is taking positive steps under its VA and can accurately measure, and report on, the savings achieved.

Status of the EMPRESS Project

The objectives of the EMPRESS Project are to:

- establish detailed business plans for M&T ESCOs in various C&EE countries, including identifying specific GEF/UNEP involvement in implementing the full-scale project;
- establish initial commitments for the M&T ESCO service from a number of end-user companies in selected companies; and
- investigate financing options for the M&T ESCO businesses.

Figure 2
Target-setting



At the time this article was written (August 2000), the project was entering its final stages, as outlined below.

In-country activities

The early examination of economic and market conditions across C&EE led to the conclusion that Poland, Hungary and the Czech Republic are the countries currently best suited to the M&T ESCO approach. It is here that our efforts have been concentrated.

Widespread discussions have been held with potentially interested parties, including government ministries, local financial institutions, utilities and industry associations. All have expressed support for the concept. Several seminars for potential end-users have been held in each country. These have led to a number of organizations expressing interest in being one of the pilot host sites. It is intended that most of the pilot sites will be in the industry sector, as this is where the greatest barriers exist. The aim is to develop six suitable demonstrations in each country.

These companies have been screened to check their suitability for the service, particularly in respect of their financial standing, energy expenditure and extent of energy metering. The most promising are currently being audited to determine:

- potential savings from implementing M&T;
- the costs of new metering and data collection systems; and
- the attitudes of plant management to energy savings and M&T.

This procedure will enable us to prepare full M&T Implementation Plans, for consideration by potential investors after being fed into the Business Plan model (see below).

Common activities

In parallel with in-country activities, work has been continuing on a number of elements that will support the whole project. The most crucial have been discussions with potential project partners who will move the project forward past the initial pilot phase.

Several organizations have expressed interest in being involved in their own countries (e.g. utilities and local banks), but the ideal would be to find an organization that would cover all three target countries. Discussions have therefore been held with a number of conventional ESCOs, two of which are interested in seeing the detailed Business Plan when it is available. Both are already operating in the region. A number of potential suppliers of metering and data collection systems have also been identified.

It is worth noting that UNEP, GEF and EBRD (the European Bank for Reconstruction and Development) have expressed willingness to be involved in the next stage. Their support could be vital in

reducing the risk for the eventual M&T ESCO operator.

The Business Plan model has been developed to determine such factors as investment requirements, length of contract, and percentage of savings needed to break even. Based on the theoretical (though grounded in experience) figures, the proposed business looks viable. Once the real data are available from the pilot sites, they will be used in the model to show:

- detailed estimates of the marketing and infrastructure costs of setting up activities in each country (or in the region as a whole);
- detailed estimates of the metering investments required for the first wave of M&T projects together with initial estimates of savings and, hence, income streams;
- approximate estimates of investments and income related to small project implementation in the first wave of M&T projects;
- approximate estimates of investments and income related to further waves of M&T projects;
- details from potential funding partners, including degree of interest in the project, funding available, costs involved and guarantees required.

Based on this information, it will be possible to prepare a detailed business plan for the way in which the M&T ESCO would develop over the first five years of operation. This will be used in further discussions with conventional ESCOs and other potential investors.

Conclusions

Nothing in the work we have undertaken so far has led us to believe that the EMPRESS concept is flawed – quite the opposite, in fact, bearing in mind the extent of the support we have received from a wide range of respondents. However, we have found that it is a difficult idea to explain to potential end-users. A high level of marketing effort is therefore likely to be needed in the early stages.

That the service could deliver substantial CO_2 savings without "costing the Earth" is not in doubt. The main challenge now is to develop a partnership that can turn the EMPRESS concept into a commercial reality. ◆

Case study: utility savings at a glass manufacturer

Enviros implemented a utility management system at one of the largest glass manufacturers in Central Europe, Skloplast in Slovakia. The performance information from the M&T system produced gas, electricity and cooling water savings worth $115,000 per year.

Skloplast produces glass fibre, as either yarn or mats, and has five furnaces for melting glass in a continuous process.

Savings achieved:

- *Gas*: $60,000 per year through optimization of the glass furnace burners;
- *Electricity*: $40,000 per year, owing to the fact that the glass furnace electrical booster was no longer needed;
- *Water*: $15,000 per year through reuse of cooling water.

Glass furnace burners

A target was set for gas consumption by each of the furnaces, which, because of the dominant fixed losses and almost constant throughput, did not vary much from week to week. After several weeks, the M&T reports showed that the gas usage of one furnace had an increased variance of up to 6% against the target. At first, it was thought that the variance was due to a 10°C increase in the glass temperature that had been required for a quality improvement.

However, in a team meeting it was agreed that the temperature change could not fully account for the increase in gas consumption. It was therefore decided to optimize the burner fuel to air ratio. This was done in week 41, after which consumption fell to its previous level although the process temperature was now higher.

The trend graph in **Figure 1** shows the increase in usage during weeks 38 to 41. Without the performance reports produced by the M&T system, the increase in gas usage might not have been detected. In that case, prompt action would not have been taken. The higher consumption level would therefore have continued, resulting in increased gas costs of $37,000 per year.

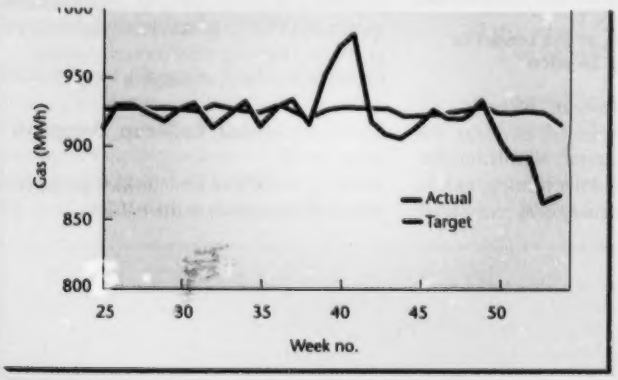
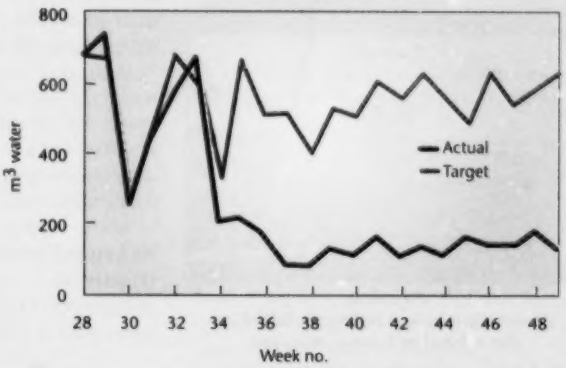


Figure 4
Dryer water consumption trend



Encouraged by this success, a second optimization of the fuel to air ratio was carried out in week 50, after which gas consumption fell well below the target. Gas costs were reduced by a further $23,000 per year. The effectiveness of this improvement meant the electrical booster could be switched off completely, giving additional savings of $40,000 per year. Through these actions, Skloplast realized total annual savings of $100,000.

Cooling water

Another area covered by the utility management system was a dryer for gluing and drying glass fibre mats. Analysis using M&T software showed that mains water consumption was very high, with little variation even at low production levels.

Investigation showed that the water was mainly used for cooling the glass fibre mats before reeling. After the cooling duty, the water was dumped to drain. The possibility of reusing the cooling water was discussed. It was decided to relocate the drainpipe to a nearby balance tank, so that the water could be reused for cleaning the belt.

The target for the dryer water consumption, based on historical performance, was related to the dryer's throughput. Reuse of the water began in week 35, after which consumption fell to less than one-third of the previous levels. The associated annual water savings were about 40,000 m^3 per year, equivalent to $15,000 (**Figure 2**).

Energy efficient design and renewable energy use in educational buildings: the MEDUCA project

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The MEDUCA (Model EDUCAtional buildings) project encompasses eight demonstration projects in seven countries. These projects are located in Grong, Norway (65° N); Göteborg, Sweden (58° N); Falkenberg, Sweden (57° N); Ballerup, Denmark (56° N); Neumünster, Germany (54° N); Almería, Spain (36°50' N); Bagheria, Italy (38° N); and Legraina, Greece (38° N).

The MEDUCA project has been in operation since January 1997. Several building projects have been completed, and monitoring is taking place. The results of the coordinated analysis, monitoring and evaluation of these projects will be compiled, evaluated and disseminated through a series of three thematic reports covering ventilation, daylighting and control. The reports will present building designers with the results of design studies and an evaluation of monitored data on the building projects. A summary report (working title: *Solar Schools*) describing each project, aimed at decision-makers, will be produced. All material from the project will be made available on a CD-ROM and distributed.

It is expected that through demonstrating integrated energy efficient innovative technologies and comfort improvement, and through the participants' cooperation and exchange of experience, this collaborative project will have a significant impact on the general perception of energy efficient buildings. In particular, it is expected to serve as the basis for improved energy (and comfort) standards for educational buildings in participating countries and in Europe as a whole.

Expected energy savings and reduced emissions for individual projects are in the range of 50-60% for thermal and 30-50% for electricity. The figure for overall emissions reductions is around 50%.

The following is a short description of each project and its status, including a summary of new energy efficiency and renewable energy technologies.

◆◆◆◆◆

Figure 1
Ventilation tower being installed at the school in Grong, Norway

School in Grong, Norway (Figures 1 and 2)

Building type: One-storey school.
Building area involved in project: 1000 m².
Primary technologies: Use of solar energy for space heating and pre-heating of ventilation air. Use of daylight to reduce dependency on high-grade electric energy for artificial lighting.
Ventilation is based on natural driving forces, buoyancy and wind, and a minimum of fan power. Airflow controlled by CO_2 sensors, heat recovery, and low-emitting building materials contribute to energy efficiency.
Construction was completed in 1998.

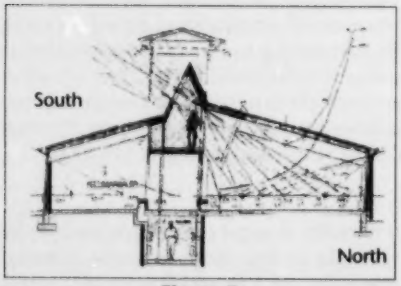

Figure 2
Daylight design study sketches for the school in Grong

Hökegård school, Göteborg, Sweden (Figure 3)

Building type: One-storey school (renovation of school built in 1964).

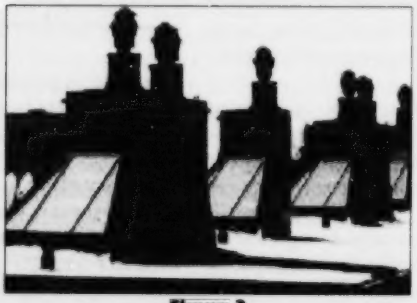

Figure 3
Daylight monitors at the school in Göteborg, Sweden

Building area involved in project: 2350 m².
Primary technologies: Optimized envelope, low energy windows, heat recovery ventilation, hybrid ventilation, passive solar heating, passive cooling, advanced control system and BEMS (Building Energy Management System), optimized daylighting, energy efficient lighting, solar control/shading.
The refurbished school was inaugurated by the Queen of Sweden in August 1997.

Figure 4
Ventilation tower and daylight roof windows at the Egebjerg School

School in Falkenberg, Sweden

Building type: School for 7th to 9th grades (renovation of school built in 1968).
Building area involved in project: 9350 m².
Primary technologies: Low energy windows, heat recovery ventilation, hybrid ventilation, passive solar heating, passive cooling, advanced control system and BEMS, optimized daylighting, energy efficient lighting, solar control/shading.
Construction was completed in 1999.

Egebjerg School, Ballerup, Denmark (Figure 4)

Building type: School for 1st to 10th grades (renovation of school built in the 1970s).

Building area involved in project: 1700 m².
Primary technologies: Improved insulation, low energy windows, fan-assisted natural ventilation, ventilation air pre-heating and pre-cooling in earth ducts, ventilation air preheating in perforated absorber solar wall, advanced control system and BEMS, optimized daylighting, energy efficient lighting and solar control/shading.
Refurbishment was completed in 1998. A qualitative evaluation of air quality in the renovated compared to the non-renovated part, conducted among 200 teachers and pupils, indicated a significant improvement in air quality. The monitoring results show a 45% reduction in heating energy consumption.

Wittorfer School, Neumünster, Germany (Figure 5)

Building type: Renovation of several school buildings of varying age. Low energy windows and additional heat protection for the pavilion and for the partial single glazed windows at the extension building.
Building area: 5275 m².
Primary technologies: Change of energy supply from gas to district heating. Advanced control

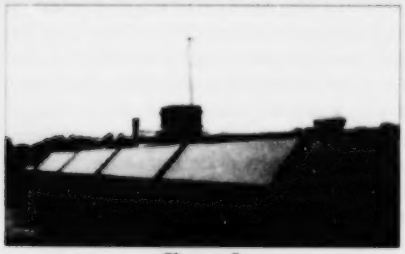

Figure 5
Solar collectors and windmill on the roof of the Neumünster school

systems. Single room control system for classrooms, gymnasium, sports hall and the most important functional rooms. BEMS includes energy management and indoor climate monitoring (CO_2 and relative humidity). Daylight and timetable dependent low-energy artificial lighting systems in classrooms and corridors. Solar hot water for showers in the sports hall.
Project completed in spring of 1999.

University of Almería, Spain (Figure 6)

Building type: Active clerestory roof. Renovation of atrium.
Building area involved in project: 450 m².
Primary technologies: Solar control integrated in new roof construction, natural ventilation,

Figure 6
Outside view of retrofitted atrium glass roof at the University of Almería

photovoltaic (PV) technology.
Manufacturing and installation completed. The monitoring phase has begun and the space taken into use.

Environment education centre, Bagheria, Italy (Figure 7)

Building type: Environment education centre (seminars, exhibitions, laboratories). New construction.
Building area: About 750 m².
Primary technologies: Daylighting, sun spaces, natural ventilation, water solar collectors with seasonal storage, PV panels, solar-assisted heating/cooling systems are integrated in this building to demonstrate autonomous design by maximizing use of renewable energy.
Building and systems design completed. All building permits received by October 1998.

Figure 7
Sketch showing external view of the education centre planned to be built in Bagheria

Design approved 12 August 1998. It has not been possible for the Italian partners to start work in time to allow construction, monitoring and evaluation within the contract period of the MEDUCA project.

European Public Law Centre, Legraina, Greece (Figure 8)

Building type: Multi-use educational building. New construction.
Building area: 2000 m².
Primary technologies: The buildings incorporate an energy design for optimal exploitation. The concept includes passive solar heating and cooling, natural ventilation, daylighting and artificial lighting, solar air collectors, geothermal heat pumps and water solar collectors.
Construction is ongoing. It is to be completed by the end of August 2000.

Figure 8
Computer graphic showing the new European Law Centre building at Legraina

Acknowledgements

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LEAP2000: tools for sustainable energy analysis

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Summary

LEAP2000 is a collaborative initiative, led by the Boston Center of the Stockholm Environment Institute, to create a new suite of analytical software and databases for integrated energy-environment analysis. The products of the LEAP2000 initiative will be available for wide dissemination in early

Résumé

LEAP2000 est une initiative de collaboration qui vise à créer, sous la direction du Boston Center de l'Institut de l'environnement de Stockholm, une nouvelle série de logiciels et de bases de données analytiques permettant une analyse intégrée énergie – environnement. Destinés à une large diffusion, les produits LEAP2000 devraient être disponibles début 2001. L'article présente les principales caractéristiques de ces produits.

Resumen

LEAP2000 es una iniciativa de colaboración dirigida por el Centro de Boston del Instituto Medioambiental de Estocolmo y orientada a la creación de una nueva serie de bases de datos y programas informáticos para el análisis integral de los nexos entre la energía y el medio ambiente. Los resultados de la iniciativa LEAP2000 estarán disponibles para una amplia difusión a principios del año 2001. Este artículo resume los rasgos básicos de estos productos.

The past two decades have witnessed major shifts in energy policy. As prices softened in the years following the oil crises of the 1970s, the issues of energy security and the price of fossil fuels receded from the forefront of energy concerns. In their place a new agenda gradually evolved, dominated by market reform, sustainable development and global climate change.

In addressing these concerns, policy-makers face multiple (and often conflicting) challenges: expanding the supply of affordable and reliable energy; minimizing environmental impacts; improving energy efficiency; attracting capital investment; spurring local development; and balancing the concerns of numerous stakeholder groups. Developing countries face the daunting challenge of providing nearly 2 billion people with access to modern fuels. Dealing with these issues requires a broad view of the role of energy in meeting economic, social and environmental objectives. It also requires practical understanding of numerous policies and projects, ranging from broad economic policies (e.g. tax and price reform) to numerous specific measures (e.g. rural electrification and low-emission vehicle technologies).

In 1997, SEI-Boston joined forces with five leading international research and training institutions[1] to create a new suite of tools for integrated energy-environment analysis. Funded by the Dutch Ministry of Foreign Affairs (DGIS), the LEAP2000 Initiative is designed to meet the needs of energy and environmental professionals around the world.

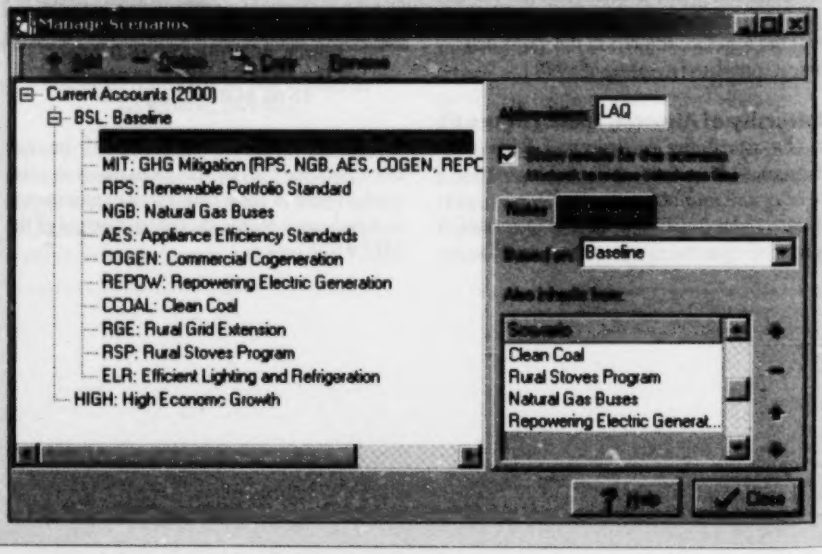
Major outputs include a new software tool (also called LEAP2000), a Technology and Environmental Database (TED), capacity building activities, and companion training materials. This initiative builds upon 20 years' experience in over 60 countries using earlier versions of the LEAP (Long-range Energy Alternatives Planning) system to advance integrated energy policy assessment (SEI-Boston, 1995). LEAP has been used to develop local, national and regional energy strategies, conduct greenhouse gas mitigation assessments, and train professionals in sustainable energy analysis. The products of the LEAP2000 initiative will be available for wide dissemination in early 2001. This article summarizes their key features.

LEAP2000 software

The LEAP2000 software system (SEI-Boston, 2001) is a scenario-based energy-environment modelling tool. Its scenarios are based on comprehensive accounting of how energy is consumed, converted and produced in a given region or economy under a range of alternative assumptions regarding population, economic development, technology, price and so on. With its flexible data structures, LEAP2000 allows for analysis as rich in technological specification and end-use detail as the user chooses.

Figure 1
LEAP2000 Scenario Manager

In this illustration, various individual measures are combined into two overall scenarios. The Greenhouse Gas Mitigation scenario (MIT) contains a comprehensive set of measures for reducing greenhouse gas emissions, while the more limited Local Air Quality scenario (LAQ) is confined to measures that address urban air pollution problems. Note also the alternative baseline scenario (HIGH).



With LEAP2000, the user can go beyond simple accounting to build sophisticated simulations and data structures. Unlike macroeconomic models, LEAP2000 does not attempt to estimate the impact of energy policies on GDP or employment, although such models can be run in conjunction with LEAP2000. Similarly, LEAP2000 does not automatically generate optimum or market-equilibrium scenarios, although it can be used to identify least-cost scenarios. Important advantages of LEAP2000 are its flexibility and ease of use, which allow decision-makers to move rapidly from policy ideas to policy analysis without having to resort to using more complex models.

At the heart of LEAP2000 is the process of scenario analysis. Scenarios are self-consistent storylines of how an energy system might evolve over time in a particular socio-economic setting and under a particular set of policy conditions. Using LEAP2000, scenarios can be built and then compared to assess their energy requirements, social costs and benefits, and environmental impacts.

The LEAP2000 Scenario Manager is used to describe individual policy measures and to combine these into alternative scenarios. For example, in **Figure 1** a series of individual measures have been developed, including a renewable portfolio standard, appliance efficiency standards and low-emission vehicles. These and other measures can be examined individually and then combined into integrated scenarios that capture their interactions (e.g. the benefits of appliance efficiency standards, combined with a renewable portfolio standard, will be less than the sum of the benefits of the two scenarios considered separately). The Scenario Manager enables the creation of a wide range of scenarios for fashioning comprehensive strategies and for assessing the sensitivity of results to uncertainty in key variables. Using LEAP2000's reporting features, each scenario can be compared and evaluated against a wide range of locally defined objectives (e.g. expanding energy services, improving air quality, etc.).

Transparency and ease of use

LEAP2000 provides significant advances over earlier generations of modelling tools, with its intuitive and familiar ways of editing data and reviewing results. One example of this approach is in the "Diagram View", which automatically represents data structures in the form of a standard Reference Energy System diagram that can be directly edited by the user (**Figure 2**).

LEAP2000 is structured as a series of "views" of an energy system. The main "Analysis View" is shown in **Figure 3**. In this view, a standard hierarchical tree is used to create data structures for the demand, transformation (i.e. conversion of energy in power plants, oil refineries, etc.) and resource analyses. These structures can be edited to reflect the level of disaggregation and detail appropriate for the particular application. The tree uses standard operations (copying, pasting, dragging and dropping, etc.) that dramatically simplify the construction and maintenance of the data structures required in an end-use oriented energy analysis.

The tree affords a great deal of flexibility in how a system is modelled. As shown in Figure 3, for example, a demand model might consist of many levels of disaggregation in a sector where a detailed, technology-based analysis is required (e.g. households), coupled with simpler aggregate analyses in sectors where energy use is less important or less well understood (e.g. agriculture). For each branch, future activity levels (passenger-km of travel, population, industrial value added, etc.) and energy intensities can be specified exogenously, or calculated as a function of other variables (e.g. car ownership could be a function of income).

Intuitive and easy-to-use reporting is another

Figure 2
LEAP2000 Diagram View

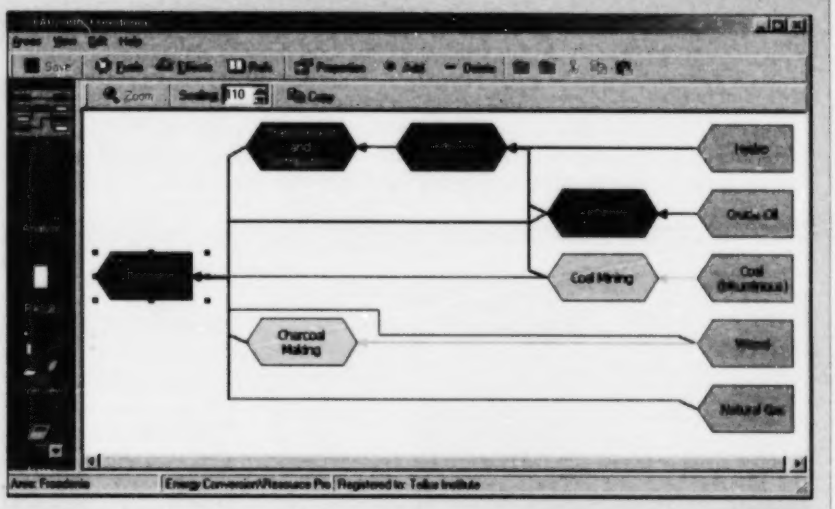


Figure 3
LEAP2000 Analysis View

Icons on the far left of the screen show different "views" of the energy system. Next to this "view bar" is the tree used to organize data structures (the Household sector has been selected here). The data entry pane on the top right of the screen shows a projection of the share of households in each of three sub-sectors for a Reference scenario (selected at the top). Note the "Interp" functions used in this example to interpolate the shares of urban and rural electrified households from the base year to 2030, and the "remainder" function used to calculate the remaining share of non-electrified rural households. Many alternative built-in functions are available, or users may construct their own. The data are also shown graphically in the chart at the bottom right of the screen.

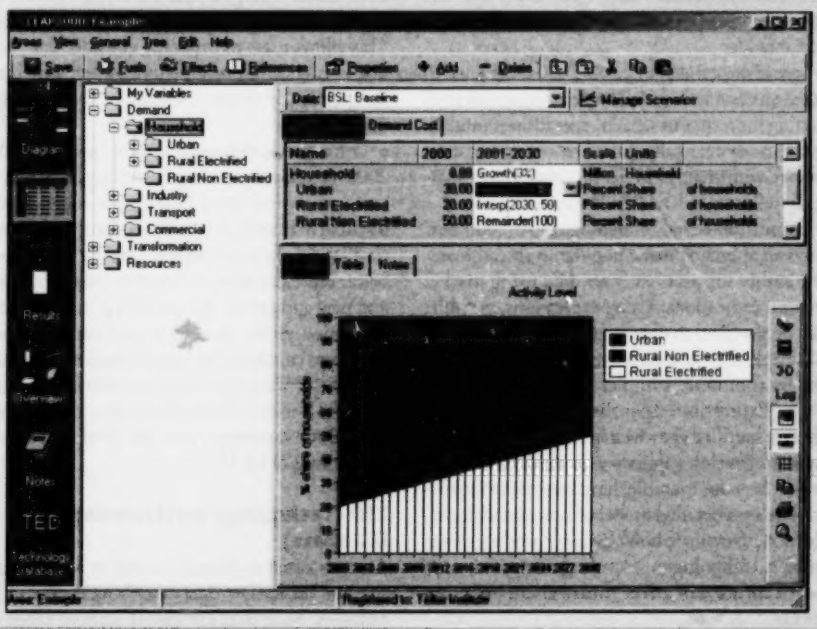
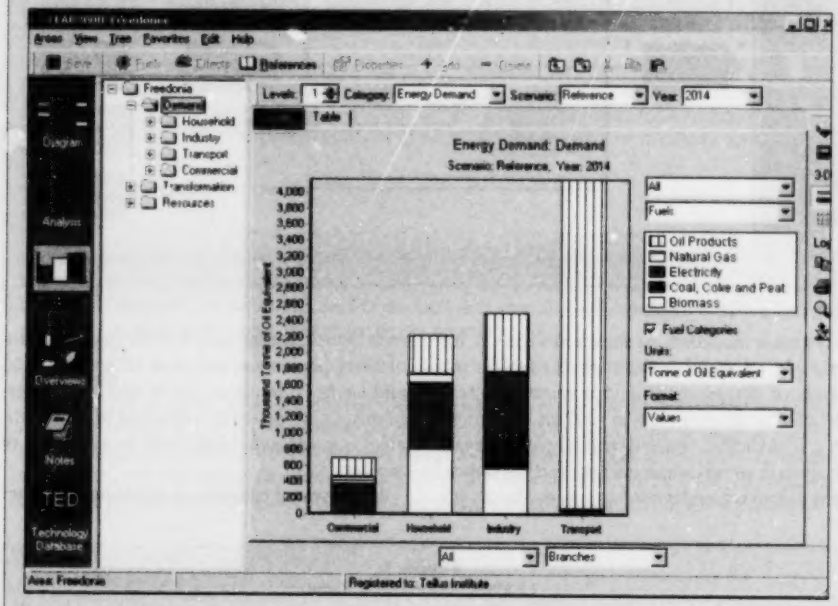


Figure 4
LEAP2000 Results View

The task of producing reports in LEAP2000 is reduced to simply configuring a graph or table. The user first picks a result category from the toolbar above the chart and then chooses which data to display on the chart's X axis and legend. The tree used in the Analysis View is also used in the Results View, to drill down from more aggregate to more detailed results. Numerous options are available for configuring charts, including selecting units, data formats and the type of chart. Alternatively, users can see the information in table format by clicking the tab at the top of the screen. Results can also be exported to spreadsheets with a single mouse click.



key ingredient of LEAP2000, helping users to interpret results and catch errors. The "Results View" shown in **Figure 4** illustrates this. Selecting among the many reports available in LEAP2000 is made simple and visual.

Analytical advances

LEAP2000 includes important analytical advances over earlier versions of the system. Examples include:

- **Spreadsheet linkages**: LEAP2000 is designed to act as an open framework for organizing and integrating the results of separate spreadsheet models. It can be dynamically linked to any spreadsheet model, with changes in the spreadsheet automatically reflected in LEAP2000's results.
- **Expression-based modelling**: LEAP2000 borrows an approach made popular in spreadsheets, the ability for users to enter data using mathematical expressions. Using expressions, variables can be specified to change over time on the basis of simple step or interpolation functions, or on the basis of more complex modelling relationships. Expressions may also reference variables that are specified elsewhere in the system, allowing users to develop sophisticated models. Chinese researchers, for example, have used these features to develop a detailed model of iron and steel production, to evaluate how changing product mixes, process technologies, recycling rates, and waste heat capture will affect future energy requirements.
- **Software wizards**: LEAP2000 includes a range of software "wizards" that take users step-by-step though some of the more complex analytical tasks in the software, for example helping them specify the correct parameters for a given expression.
- **Optional useful energy demand analysis**: LEAP2000 includes the optional ability to conduct "useful" energy demand analysis, in addition to the standard final energy analysis approach. This allows users to explicitly consider demand-side efficiency improvements and fuel switching independently of the evolution of useful energy demands.
- **Other methodological improvements**: LEAP 2000 includes numerous methodological advances over earlier versions of LEAP, such as cost-based dispatch of electric power plants, more automated simulation of electric sector capacity expansion, better representation of intermittent renewables, and new approaches for modelling industrial cogeneration. At the same time, backwards compatibility was considered an important design goal for the new software, given the large number of existing LEAP users. To accommodate these users, LEAP2000 can import data sets developed in earlier versions of LEAP.

TED (Technology and Environmental Database)

Analysts often need ready access to comprehensive and up-to-date data describing energy technologies. Such data are spread across a range of sources that are not easily accessible, particularly to analysts in developing countries. To address this problem, LEAP2000 includes a Technology and Environmental Database (TED) that provides extensive information describing the technical characteristics, costs and environmental impacts of a wide range of energy technologies, including existing technologies, current best practices and next generation devices.

The first version of TED includes data on approximately one thousand technologies, referencing reports by dozens of institutions including the Intergovernmental Panel on Climate Change (IPCC 1996), the US Department of Energy (US-DOE and EPRI 1997) and the International Energy Agency (NEA/IEA 1998), as well as by LEAP2000 partner institutions which have developed data specific to energy technologies found in developing countries. In addition to its quantitative data, TED also includes qualitative information pages (an example of which is shown in **Figure 5**) that review the availability, appropriateness, cost-effectiveness and key environmental issues associated with a wide range of energy technologies. TED can be used as a stand-alone tool or, as an integral part of the LEAP2000 system, it can be used to calculate the environmental loadings of energy scenarios. TED's own core database of emission factors can be edited or supplemented by a user's own data.

Capacity building using LEAP2000

LEAP's transparent methods and easy-to-use design make key energy policy questions easier to grasp. It has been an important tool in the training programmes of national and regional energy institutions in all major regions of the world for over 20 years. A range of new training materials have been developed to accompany LEAP2000, including exercises designed specifically for regional applications (available in local languages). These materials are designed to draw out typical energy-environment policy dilemmas, and to encourage trainees to think about the trade-offs inherent in different policy options. A number of regional training workshops are being held in late 2000 and early 2001, and more are planned.

Conclusion

LEAP2000 and TED are expected to be available for general use during the first quarter of 2001. At that time, evaluation versions will be made available for download from the Internet (www.leap2000.org) and on CD-ROM (contact: leap@tellus.org). Full versions of the tools will be made available, based on a license agreement. Licenses are available at no charge to government, non-profit and academic institutions based in developing countries.

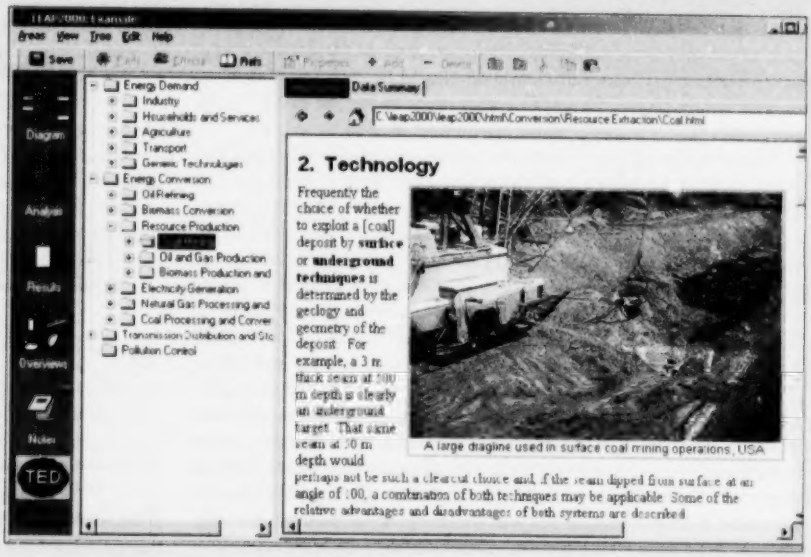
The LEAP2000 web site includes additional information, including a discussion of LEAP applications. LEAP2000 is currently being applied in a number of projects, including a Chinese-US research effort to examine alternative energy futures and an integrated resource planning project in Ghana.

Further developments to the LEAP2000 and

TED software and databases are planned, driven by the evolving needs of users. Plans for the immediate future call for expanding the TED database, with particular emphasis on providing reliable default values for a comprehensive set of technologies and pollutants. Energy policy and sectoral analysis "toolkits" are under consideration to assist those conducting specific types of analyses. As the energy agenda and information technology continues to evolve, so will tools like LEAP.

Figure 5
TED: Technology and Environmental Database

A sample information page on coal mining from TED. As in LEAP2000, a standard tree is used to navigate through the information pages and quantitative data stored in TED.


Save
Diagram
Analysis
Results
Overview
Notes
TED
Energy Demand
Industry
Households and Services
Agriculture
Transport
Energy Conversion
Biomass Conversion
Resource Production
Oil and Gas Production
Biomass Production and
Electricity Generation
Natural Gas Processing and
Coal Processing and Conver
Pollution Control
Data Summary
2. Technology
Frequently the choice of whether to exploit a [coal] deposit by surface or underground techniques is determined by the geology and geometry of the deposit. For example, a 3 m thick seam at 200 m depth is clearly an underground target. That same seam at 20 m depth would perhaps not be such a clear-cut choice and, if the seam dipped from surface at an angle of 100, a combination of both techniques may be applicable. Some of the relative advantages and disadvantages of both systems are described
A large dragline used in surface coal mining operations, USA

Note

1. The LEAP2000 partner institutions are EDRC (South Africa), ENDA (West Africa), ETC (Europe), FAO-RWEDP (Asia), IDEE (Latin America) and SEI-B (North America). These acronyms stand for the Energy and Development Research Centre (www.edrc.uct.ac.za), Environnement et Developpement du Tiers Monde (www.enda.sn), the ETC Foundation (www.etcint.org), the Instituto de Economía Energética of the Fundación Bariloche (www.bariloche.com.ar/ideefb), the Regional Wood Energy Development Programme of the FAO (www.rwedp.org), and the Stockholm Environment Institute - Boston Center (www.seib.org).

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RETScreen™ International: a decision support and capacity building tool for assessing potential renewable energy projects

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Most countries have ample renewable energy resources available to them, such as sun, wind, water, biomass and/or geothermal. Renewable energy technologies (RETs) are sufficiently developed and reliable to meet an increased proportion of the world's energy needs. In fact, renewable energy projects are presently cost-effective in a number of applications.

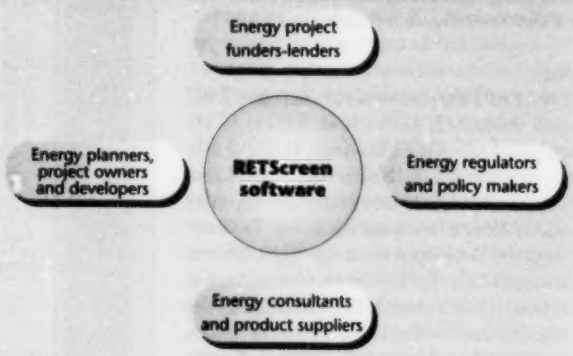
"Global climate change mitigation particularly depends on widespread use of these technologies in all countries. These technologies can also advance important national development goals, such as cleaner air, energy services for rural populations, and more efficient domestic industries. Many opportunities exist to utilize these technologies, although realization of opportunities is often constrained by many barriers."[1] The barriers include "lack of information about technologies, opportunities, costs and benefits; lack of human resource and institutional capacities to evaluate, finance and conduct investment projects; high transaction costs; and other institutional constraints."[2]

As a result of these barriers, RET projects are not routinely considered by utility planners, government policy-makers, bankers, engineers, architects and other decision-makers at the critically important initial planning stage, even where they have proven cost-effective and reliable in similar situations. If RET projects are not put "on the table" up front, it is usually impossible to have them considered later in the energy project or programme development process. The RETScreen Renewable Energy Project Analysis Software was developed to address this important problem.

RETScreen International

RETScreen International is an innovative and unique renewable energy awareness, decision support and capacity building tool developed by Natural Resources Canada's CANMET Energy Diversification Research Laboratory (CEDRL) with the contribution of over 70 experts from industry, government and academia (see http://retscreen.gc.ca). Its core consists of a standardized and integrated renewable energy project analysis software that can be used worldwide to evaluate energy production, life cycle costs and greenhouse gas emission reductions for various types of RETs. In addition to the software, RETScreen includes: product, cost and weather databases; an online manual; a website; project case studies; and a training course.

Figure 1
Common project evaluation platform


Energy project funders-lenders
Energy planners, project owners and developers
RETScreen software
Energy regulators and policy makers
Energy consultants and product suppliers

The new UNEP GHG model

UNEP's Division of Technology, Industry and Economics (DTIE) and CEDRL are cooperating to increase awareness and enhance the usefulness of RETScreen. They have concluded that one way to bring about an increase in RET investments is to help project promoters and their financial backers better analyze the technical and financial viability of possible projects. As part of this collaboration, UNEP DTIE and CEDRL have developed a new greenhouse gas emissions mitigation model for RETScreen, with funding from the Global Environment Facility. The UNEP Collaborating Centre on Energy and Environment has also participated in this work. The new GHG model allows users to estimate the greenhouse gas emissions avoided, as well as the Clean Development Mechanism (CDM) and Joint Implementation (JI) financial impacts of the proposed RET project. Use of this model simplifies calculation of GHG emissions. It results in substantial cost savings for users, and increased government and industry opportunities for CDM and JI projects.

New NASA global satellite data

There is also cooperation between the US National Aeronautics and Space Administration (NASA) and CEDRL to facilitate use of NASA's global satellite solar data with RETScreen, and to develop a new global weather database (see http://eosweb.larc.nasa.gov/sse) for this tool. Sponsored as part of NASA's Earth Science Enterprise Programme, the work is being carried out at the NASA Langley Research Center and at CEDRL. This collaboration makes it possible for RETScreen users to access (free of charge) satellite data such as the amount of solar energy striking the Earth's surface and global temperatures and wind speeds, simply by clicking on links in the RETScreen software or on NASA's website. These data, which were previously available only from a limited number of ground monitoring stations, are critical for assessing the amount of energy a RET project is expected to produce. Use of the data results in substantial cost savings for users and increased market opportunities for industry, while allowing governments and industry to evaluate regional renewable energy resource potential.

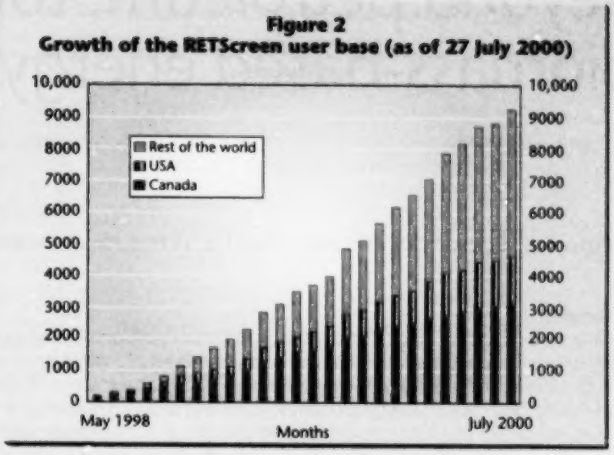
Use of RETScreen

Numerous people worldwide have been using this tool for a variety of purposes, including: preliminary feasibility studies; project lender due diligence; market studies; policy analysis; information dissemination; training; sales of products and/or services; project development and management; and product development/R&D.

For example, RETScreen was instrumental in helping CEDRL and a team of 11 consulting firms prepare preliminary feasibility studies for 56 potential RET projects at a cost of less than $2000 each. Similar studies would otherwise have cost in the order of five to ten times this amount! The money saved is being used to develop a number of these projects. The software also facilitates project implementation by providing a common evaluation platform for stakeholders involved in the project, as shown in **Figure 1**.

To illustrate how this could work, the RETScreen software files, which are in Excel format, can be shared among the various project stakeholders. A consultant may be asked to prepare a RETScreen study for the project owner, such as an independent power producer (IPP). The IPP may then want to change input values as part of a sensitivity analysis of key parameters, such as return on investment. The IPP, in turn, may be asked by the potential lender to submit the file for use in project due diligence review. In parallel, the utility regulator may want the project file to verify the GHG estimates, and so on. The time and costs required to complete this process are reduced dramatically using RETScreen.

Figure 2
Growth of the RETScreen user base (as of 27 July 2000)



Substantial international uptake

RETScreen has had a rapid uptake around the world. Since its release in May 1998, close to 10,000 users in over 170 countries have licensed a copy of the software (free of charge) from CEDRL. Expansion of the user base is shown in **Figure 2**. Demand is increasing at the rate of about 100 new users per week, and significant growth is now taking place outside Canada.

Rapidly increasing use of RETScreen around the world, recent development with UNEP of the GHG model, and access to global satellite data from NASA are all contributing to make RETScreen an international standard for RET project evaluations. Use of the software by planners and decision-makers increases their capacity to easily consider RET projects at the critically important initial planning stage. This will help accelerate deployment of environment-friendly RETs while saving a substantial amount of money and time.

Notes

1. Martinot, Eric and Omar McDoom (1999) *Promoting Energy Efficiency and Renewable Energy: GEF Climate Change Projects and Impacts*, pre-publication draft, Global Environment Facility, October.
2. Ibid.

Beyond petroleum: towards a biomass-based energy future

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Summary

Efficient biomass energy systems stand a good chance of commercial success if they use materials with a low opportunity cost, require only low levels of capital input, and have built-in flexibility. Development of these energy systems requires consideration of needs for greater energy autonomy and overall energy efficiency; rural and urban development trends; emergence of environmentally sounder conversion and utilization technologies; and ways to achieve the greatest possible carbon recycling. Particular attention is given to the development of ethanol fuels in Brazil.

Résumé

Les systèmes qui utilisent efficacement l'énergie de la biomasse ont de grandes chances d'être un succès commercial pour peu qu'ils utilisent des matériaux à faible coût "contextuel", exigent un faible apport de capital et présentent une flexibilité intrinsèque. Le developpement de tels systèmes demande qu'on prenne en considération la nécessité d'une plus grande autonomie énergétique et d'un meilleur rendement énergétique global, les tendances du développement rural et urbain, l'émergence de technologies de transformation et d'exploitation plus respectueuses de l'environnement, et enfin la recherche de moyens pour recycler le maximum de carbone. Au Brésil, une attention particulière est accordée à la mise au point de combustibles à base d'éthanol.

Resumen

Los sistemas energéticos eficientes, basados en el uso de la biomasa, tienen buenas posibilidades de éxito comercial, siempre que empleen materiales con bajo costo de oportunidad, requieran sólo niveles reducidos de inversión de capital y tengan una flexibilidad implícita. El desarrollo de estos sistemas exige que se tomen en cuenta la necesidad de mayor autonomía energética y de eficiencia general, las tendencias del desarrollo rural y urbano; el surgimiento de tecnologías de uso y conversión más beneficiosas para el medio ambiente; y los métodos de lograr el máximo reciclaje posible del carbono. El texto consagra especial atención al desarrollo de los combustibles a base de etanol, que se ha realizado en Brasil.

Biomass in various forms has been our primary energy source from time immemorial. It is only in the relatively recent history of humankind that other sources of energy, especially fossil energy (which is derived from old biomass), have furnished the bulk of energy supply.

However, biomass energy systems are now receiving worldwide attention. It is expected that the application of science and technology to biomass resources, conversion and end-use will lead to "modern" biomass energy systems. The major driving forces behind this trend have been:

- security of supply;
- local environmental quality;
- (more recently) global climate change;
- overall concern about energy systems' sustainability.

In a 1993 study by the Stockholm Environment Institute Boston Centre, for Greenpeace International, scenarios were developed for complete elimination of fossil fuel combustion and nuclear energy by the year 2100. Biomass for energy would be produced sustainably, with no net atmospheric carbon emissions. This would entail biomass productivities lower than those assumed in other studies. By 2100, *all* energy would come from solar/wind, biomass and other renewables.

Land requirements according to these scenarios would vary from 380 to 830 million hectares, or might be as little as 250 million hectares, the equivalent of 3% of total current global cropland, permanent pastureland, and forest and woodland. In 2100, electricity would be generated from solar/wind (55%), co-generation (22%), biomass (13%) and hydro/geothermal (10%). The transport sector would switch from fossil fuels to biofuels (20%), electricity (40%) and hydrogen (40%).

The biomass "energy factory"

It is helpful to consider the production elements of such biomass energy systems as part of a generalized biomass *"energy factory"* whose components are the farm/forest and the conversion processes. The links between these components and with the world outside the "factory" are transportation flows that either consume energy directly or carry the energy used to manufacture the goods.

In simplified terms, the *"farm"* component of the energy factory captures solar energy via photosynthesis and makes mainly polysaccharides (of different complexity) from CO_2 and water. This component requires other inputs, including labour, transportation fuels, and the energy associated with all material inputs to the process and the agricultural equipment used. An overview of the productivity of some typical farm components of the generalized biomass energy factory is presented in **Table 1**.

The farm component operates in symbiosis with the *"conversion"* component. This component could employ one or more processes to convert biomass produced in the farm component, including thermal, biological and extractive processes to produce liquid, gaseous and solid fuels plus residues. Like the farm component, the conversion component requires energy and material inputs. **Tables 2 and 3** describe thermal and biochemical conversion.

Key issues affecting market penetration

Key issues affecting market penetration by biomass energy include:

- opportunity cost;
- capital requirements;
- production costs;
- lead times involved;
- roles of governments and other stakeholders;
- conversion process flexibility.

The *opportunity cost* of energy resources is a direct function of these resources' uses in a particular setting. Historically, alternative uses of energy resources as chemical feedstock and sources of food, feed and fibre (including construction materials) have typically commanded higher prices than fuels. The short-term rationale for commercial biomass energy conversion therefore relies on political judgement and social (rather than commercial) cost-benefit analysis.

A significant barrier to sizeable market penetration by biomass energy would be the staggering *capital requirements*. This raises the issue of economies of scale. The range of plant capacities for energy from biomass can be very broad. For example, the capacities of typical methanol from biomass conceptual plants being considered could be much greater than the production of ethanol distilleries now in operation in Brazil.

Biomass energy's *production costs* are still a major stumbling block to increased market penetration. It is claimed that front-end government subsidization and funding during the early phases of

national biomass energy programmes are the necessary costs of prudent insurance against the occasional turbulence of the energy market. Whether this consideration is wise, and the social costs during the transition phase justifiable, only history will tell.

The *lead times* for meaningful market penetration by forms of energy are likely to be long under normal circumstances. It may be wise to consider an initially limited but growing share of the energy market for "modern" biomass energy resources in countries with the appropriate resource base, and imports of liquid biofuels in other countries. Gaseous and solid fuels derived from biomass are likely to be confined to markets in the immediate vicinity of the resource conversion.

Meaningful market penetration by biomass energy resources, replacing or supplementing the traditional pool of energy (forms and end-uses), will require some type of *government* intervention. High capital requirements and long lead times imply large sums of patient money. In view of the myriad options often available, all competing for scarce funds, there will be a need to rank candidate resources, conversion and end-use technologies according to priority. The sustainability of that determination will increase if backed by consensus among relevant *stakeholders*. To help an infant "modern" biomass energy industry take off, if conditions and requirements favour such development, governments may for a limited time consider such practices as "pulling by purchase", or legislation and regulations temporarily favouring biomass energy over traditional forms. A major challenge to governments is to assure an orderly transition to new energy resources, conversion and end-use at reasonable social costs.

Flexibility is a key process attribute in ranking the priority and potential of biomass energy conversion processes. Worldwide, ongoing R&D efforts are aimed at expanding the spectrum of energy resources and utilization. Of special importance are the prospects for utilizing residues in general as sources of ethanol and methanol. Such efforts, if successful, could alleviate the so-called "food versus fuel" conflict for land-intensive biomass and help reduce the technical and commercial risk of synthetic fuel ventures. Flexibility should be planned at the R&D stage and extended to the engineering phase. Projects designed to enable later incorporation of upcoming technological developments in processes and equipment would have the best chance of not becoming obsolete.

Table 1
Overview of the farm component of the biomass energy factory

Farm component	Status	Primary fuels	Overall energy productivity (GJ/ha/yr)*	Key issues
Food crops				
• sugarcane	commercial	ethanol	75	• high edaphoclimatic requirements • food versus fuel • six-month harvest season
• corn	commercial	ethanol		• commercial cost
• mandioca (cassava)	development	ethanol	50	• process energy supply • scale-up problem • food versus fuel, fodder • commercial cost
• palm oil kernels	commercial/ development	vegetable oils	195	• suitability of direct use in diesel engines
• rapeseed	commercial	methyl/ethyl esters of veg. oils		• surplus glycerine mkt in case of esters • food versus fuel • commercial cost
Fiber crops				
• forests	commercial/ development	firewood fuelgas (a) charcoal methanol ethanol (b)	180 175 155 50 35/50	• forest management • growth period • exploitation of natural forests • commercial cost
Wastes/residues				
• crop residues • food processing residues • forest industry residues • manures • municipal wastes	commercial/ development	biogas firewood (c)	variable	• inadequate conversion technologies • high dispersion • high water content • soil properties decline • poor nutrient recycling • commercial cost
Aquatics				
• water hyacinth • seaweeds, kelp	development	biogas	1300	• harvesting • low dry matter content • large area requirements • commercial cost

* One tonne of oil equivalent (toe) equals 42 GJ
Notes: (a) low heat content gas
(b) acid hydrolysis/enzymatic process
(c) direct combustion of cellulosic residues

Source: Adapted from Centro de Tecnologia Promon (1979) *Diagnóstico do Programa Tecnológico Industrial de Energia de Origem Vegetal (Diagnostics of the Industrial Technology Program on Biomasss-based Energy)*. Vols. 1 and 2. Report prepared for Fundação de Tecnologia Industrial, Ministério da Indústria e do Comércio, Rio de Janeiro, Brazil.

Bioalcohol fuel prospects

Oxygenated transport liquid fuels have been around since the invention of the automobile. In fact, they were Henry Ford's fuels of choice!

For a current perspective on this topic, the World Energy Council (WEC) commissioned a study, coordinated by the author, that resulted in a monograph presented and discussed at the 14th WEC Congress in Montreal in 1989. In summary, it said the following:

"Oxygenated transport liquid fuels are mixtures of alcohols or ethers in hydrocarbon fuels. Oxygenates can be used directly as fuels. They can be made from non-petroleum feedstocks and can be beneficial to the environment and stretch hydrocarbon fuels resources. Reports of the prospects of oxygenates as transport fuels were received from Member Committees of Brazil, Canada, China, India, the Federal Republic of Germany, Finland, New Zealand, Thailand, Sweden, the USA and Zimbabwe. The US Gas Research Institute, ARCO Chemical Europe and the United Nations Economic Commission for Europe reviewed the reports. Brazil, Canada-USA and China, India fitted into a cluster of countries which can take autonomous initiatives on oxygenates. Finland, Sweden and Thailand constitute a category of countries that must wait for international understandings to launch significant oxygenate programmes. New Zealand at the time chose to make gasoline from methanol from natural gas, whereas Zimbabwe implemented an E10 programme. The Federal Republic of Germany report was not analyzed for lack of time. Overall, it seems that MTBE will become a universal oxygenate for octane purposes, although its environmental impact requires further assessment. The future of methanol and ethanol as transport fuels remains an open question."

The situation has changed little since then. However, the widespread penetration of MTBE (methyl tertiary butyl ether) has suffered a setback, as it was banned in California due to concerns over leakage into the water table.

During the 1970s and early 1980s, rising crude oil prices and fears of a critical petroleum shortage sparked interest in alcohol fuels as substitutes for gasoline and diesel. In the late 1980s and early 1990s, oil prices fell dramatically, initially shifting the focus away from alcohol fuel alternatives as public concern subsided. Recent oil price increases and mounting evidence of the potential contribution of gasoline and diesel combustion to climate change have stimulated renewed interest in long-term sustainable energy solutions. Stakeholders that were once adversaries are working together to move the issues surrounding alcohol fuel development from the "why" to the "when" and, more importantly, "how".

As a reference, in Brazil today 4 million vehicles consume neat or hydrous ethanol. The balance of the fleet (some 12 million vehicles) consumes a blend of gasoline containing up to 24% ethanol by volume. In the United States, a fleet of 750,000 flexible fuelled vehicles (FFV) consumes E85, a blend containing 85% ethanol by volume, and a

large fleet consumes gasoline containing anhydrous ethanol. In Sweden, 400 buses are consuming neat ethanol. In France, ethanol is made into ETBE and blended with gasoline at some locations. In Canada, anhydrous ethanol is added to gasoline. Kenya, Malawi and Zimbabwe blend ethanol derived from sugarcane molasses in gasoline at 10% by volume. Countries actively considering ethanol fuels include Colombia and Thailand.

Table 2
Overview of biomass thermoconversion processes

Primary resulting fuel	Status	Process	Thermal efficiency (a)
Charcoal, oil, gas	Commercial	Pyrolisis	70-75% (b)
Oil, gas, charcoal	Development	Flash pyrolisis	(c)
Low-heat content gas (producer gas)	Commercial	Air gasification	70-75% (gas) 16-20% (electricity)
Medium-heat content gas	Development	Oxygen gasification	60-65% (SNG) 55-60% (methanol)
Medium-heat content gas	Development	Steam gasification	60-65% (SNG) 55-60% (methanol)
Heat Steam/electricity	Commercial	Combustion	20-30% (electricity) 75-80% (steam) 75-80% (co-generation)
Oil	Development	Direct liquefaction	50-60%

Notes: (a) All data based on wood with 50% moisture level.
(b) Gas used as energy source for on-site electricity generation and wood drying in the pyrolisis plant.
(c) Product yield very sensitive to actual conditions of flash pyrolisis.

Sources:
* Pyrolisis and oxygen gasification:
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* Liquefaction:
Kjellström, B. (1981) *Producer Gas 1980 - Local Electricity Generation from Wood and Agricultural Residues.* The Beijer Institute, Stockholm, Sweden.

Fuel cells

An important development that might encourage increased use of oxygenated fuels, especially methanol and ethanol, is the prospect of automobile power trains using fuel cells. These devices have been known for 200 years, but have been developed lately as power sources for stationary and mobile uses. Their operation can be seen as the reverse of that of a battery. Fuel cells bring hydrogen and oxygen into contact so as to react chemically in a controlled way, yielding electricity, water and heat. Hydrogen fuel can be provided directly or "extracted" from methane, natural gas, methanol, ethanol or even gasoline in the fuel preparation stage of the fuel cell.

There is plenty of public and private-led research on fuel cells in Europe, Japan, Canada and the United States. The range of unit sizes of fuel cell applications is from 0.01 to 300 kW, and unit power costs currently estimated are around US$ 10-10,000/kW.

Ethanol fuels in Brazil

Brazil's Proalcool Programme is the largest alternative transport fuels programme in the world. About 8.4 million metric tonnes of oil equivalent (mtoe) of sugarcane based ethanol was consumed in 1998 (equivalent to some 167,000 barrels of crude oil or 217,000 barrels of gasoline per day). Some 60% is neat or hydrous ethanol and 40% is anhydrous ethanol for blending with gasoline. This amount corresponds to about 20% of fuels consumed in transportation.

Total primary energy supplied to the Brazilian economy in 1998 was 250 million mtoe. The main transportation fuel is diesel oil, consumed at a rate twice as great as that of gasoline. There are three grades of gasoline: gasoline A (regular leaded) has been replaced by gasoline C, a blend of gasoline and up to 24% anhydrous ethanol by volume; gasoline B (premium) has been discontinued in Brazil due to neat ethanol market penetration.

Historically, there have been a number of stakeholders in the Brazilian transportation/fuel industry: the government; ethanol and automobile manufacturers and distributors; the petroleum and natural gas and sugarcane industries; and Brazilian and international consumers. Stakeholders' economic and social interests are often intertwined in both the national and international marketplaces.

The Brazilian sugarcane economy

In 1997, Brazil produced about 300 million tonnes of sugarcane, 25% of the world's total output. There are 70,000 sugarcane producers in the country, 90% in areas smaller than 150 hectares. The total area planted in sugarcane reaches 5 million hectares, of which about 70% in the state of São Paulo. Some 343 sugar mills and ethanol distilleries are in operation, 202 producing sugar and ethanol, 122 producing ethanol exclusively and 19 making only sugar. Overall, the industry contributes 1% of GDP.

Sugarcane bagasse is used as fuel to produce industrial steam and generate electricity for mills, distilleries and the electrical grid. Together with ethanol, it contributes 13% of the country's domestic production. The potential for surplus electricity from sugarcane bagasse and other residues in co-generation systems is estimated to be 5000 MW, about 10% of current power generation capacity. The value of avoided gasoline imports, at 200 thousand barrels a day, reaches at least US$ 2 billion per year.

Brazil's sugarcane economy generates 1 million direct jobs, of which 75% in sugarcane agriculture and 25% in ethanol production. The major producer, Copersucar, maintains a Technology Centre carrying out research, development, demonstration and extension in sugarcane agriculture and ethanol production. This Centre is engaged in a cooperative effort with 28 other institutions in Brazil to map the sugarcane genome, supported by the São Paulo state research funding organization FAPESP. The sugarcane genome is composed of at least 50 thousand genes.

Economics as if the local and global environments mattered

Production and use of fuel ethanol have promoted significant technological developments in the Brazilian sugarcane agro-industry and automotive industry. Substantial ethanol cost reductions have been achieved on a consistent basis since the programme's inception. Nevertheless, by the end of 1985 the best ethanol producer in Brazil was barely cost competitive with gasoline at a crude price of US$ 28 per barrel, equivalent to the range of oil prices in 2000.

Straight economic comparisons do not take into consideration ethanol's:

- value in reducing oil imports and foreign exchange drainage in a country as highly indebted as Brazil;
- greater value as an octane booster;
- superior environmental characteristics.

The early introduction of ethanol in automotive fuels in Brazil had considerable environmental benefits for local urban air quality, as measured by total removal of lead from gasoline and a sharp decrease in emissions of CO, unburned hydrocarbons and NO_x. Increased acetaldehyde emissions are much less preoccupying than emissions of formaldehyde from gasoline-fuelled engines. Regulatory pressure in recent years, and limited investment in the performance of ethanol-fuelled engines, have led to a considerable reduction of emissions from gasoline-fuelled engines, to the point that today they are (with the exception of

Table 3
Overview of biomass biochemical conversion processes

Fuel	Substitute for	Process	Fuel yield MJ/tonne substrate (dry)	Process energy requirements MJ/tonne	World market cost US$/barrel of oil equivalent
Methane (CH_4)	LPG	Anaerobic digestion	0.28-0.74	1.2	28
Alcohol (C_2H_5OH)	Gasoline	Hydrolysis and/or carbohydrate fermentation	0.46	1.1-1.4	68
Methyl and ethyl esters of vegetable oils	Diesel fuel	Extraction and trans-esterification of vegetable oils	0.30 (a)	0.2	97

Note: (a) Calculated as castor oil.

Table 4
Greenhouse gases emitted in production of sugarcane, sugar and alcohol, 1998

Basis: kg of GHG expressed as kg CO_2 per metric tonne of sugarcane

Production, harvest and transport of sugarcane	
Carbon sequestration via photosynthesis	+ 694.7
CO_2 from diesel used in sugarcane agriculture	- 4.7
CO_2 from burning dry leaves, tips	- 198.0
Other GHG, especially CH_4, from burning dry leaves, tips	- 1.0 to - 5.0
N_2O from soil from nitrogen fertilization	- 3.2
CO_2 from fossil fuels used in agricultural inputs (seedlings, etc.)	- 6.7
CO_2 from fossil fuels used in manufacturing agricultural implements	- 2.4
Oxidation of sugarcane residues left in the field	- 49.5
Production of sugar and alcohol (45% to sugar, 55% to alcohol)	
CO_2 from fermentation	- 38.1
CO_2 from fossil fuels used in manufacturing inputs (lime, sulphuric acid, etc.)	- 0.5
CO_2 from fossil fuels in manufacturing equipment, installations and bldgs.	- 2.8
CO_2 from burning all the bagasse, replacing fuel oil, for sugar and alcohol	- 231.6
Avoided carbon emission in sugar making by the use of bagasse	+104.0
Utilization of final products: sugar and alcohol	
Metabolic sugar carbon return to atmosphere	- 97.0
CO_2 from alcohol burned in automotive engines	- 79.1
Avoided carbon emission from automotive engines by the use of alcohol	+126.7
Total avoided emissions	**+206.8**

Source: Macedo, Isaias de Carvalho (2000) *O Ciclo da Cana-de-Açúcar e Reduções Adicionais nas Emissões de CO_2 (The Sugarcane Cycle and Additional Reductions in CO_2 Emissions)*. Centro de Tecnologia Copersucar, Piracicaba, Brazil, mimeo, March.

aldehydes) very similar. As the long-term marginal cost of oil is likely to increase, ethanol can become a rational economic option for some countries.

Growing concern about the effects of climate change have given ethanol an unexpected value, since the production and use of sugar and ethanol can avoid emissions of 207 kg of CO_2 per tonne of sugarcane (**Table 4**). The use of ethanol and sugarcane bagasse as fuels avoids emissions of 12.7 million tonnes of CO_2 annually. It has reduced Brazilian emissions of CO_2 from fossil fuels by 20%. Today sugarcane ethanol is the only commercial transportation fuel that can claim a carbon avoidance benefit, a valuable feature if the flexible mechanisms of the Kyoto Protocol become practical financial instruments in the future.

Future prospects

The key stakeholders who reached informal consensus in 1975 and 1980, in the aftermath of the two oil crises, could not agree on a common platform when oil prices collapsed in the second half of the 1980s. However, the large scale on which ethanol was being produced in Brazil means that while output is not expected to grow at the rates of the late 1970s and early 1980s, production and consumption are bound to remain high and even increase to meet growing demand for automotive fuels. Additional markets could include exports, government and public neat ethanol bus fleets, and additives to reduce particulate matter in diesel fuels.

The world view of alcohol fuels

International Symposia on Alcohol Fuels

Since 1976, there have been special gatherings of international alcohol fuels stakeholders every one to three years. What began as international discussions concerning methanol became the International Symposia on Alcohol Fuels (ISAF). The author has participated in all ISAF meetings so far.

Table 5
Biofuels programmes in Brazil, the United States, France and Sweden

	Brazil (Ethanol)	US (Ethanol)	France (ETBE, RME)	Sweden (Ethanol, biogas)
Key stakeholders	• Farming interests (sugarcane) • Ethanol makers • Oil monopoly (state) • Auto industry • Consumers (taxis) • Government (federal/state)	• Farming interests (corn growers) • Ethanol makers • Oil industry (private) • Auto industry • Consumers • Government (local/national)	• Farming interests (wheat/ sugar beets/rapeseed) • Ethanol/RME makers • Oil industry (privatized) • Auto industry • Consumers • Government	• Farming interests (grain growers) • Ethanol makers • Oil industry (private) • Auto industry • Consumers • Government
Driving forces	• 1970s oil crises/dependence • Foreign exchange bill • Falling sugar prices • 1990s environment (local)	• 1970s oil crises • Oil imports dependency • Falling demand for corn • 1990s environment (local)	• EU CAP, set aside lands • Window of opportunity for ETBE/RME • Oil imports/dependence • Environment (local) • New markets for farm produce	• Environment (local/global) • Less dependence on oil imports • New markets for farm produce
Infrastructure	• Well established since 1930s • Replacement of premium gasoline by hydrous ethanol	• Established for E10 • Niche use: vehicle fleets • Some FFV	• ETBE blends in gasoline • RME blends in stationary diesel	• Limited • Niches/fleets
Policy/programmes	• Sugarcane incentives • Fuel blend prices as gasoline • Lower prices for hydrous (neat) ethanol • R&D • Support for taxis • Government fleets	• Federal aid • State aid • R,D&D • gov't vehicle fleets with FFV/AFV	• Large tax subsidies for investment (as EU pilot) • R&D&D (AGRICE)	• R&D • Health impact studies • Limited tax incentives
Results	• Rapid introduction of E18-24 • Significant penetration of hydrous ethanol • Saturated market • Regional development • Job creation • Stakeholders' alliance ceased due to 1986 oil price crash • Technology learning curve	• World's second largest programme, but limited market penetration overall • FFV route to overcome infrastructure • Regional concentration of output • Job creation • Higher valuation of benefits req. • Need broader stakeholder consensus • Technology learning curve	• Limited market penetration • Uncertain future (ETBE versus MTBE)	• Demo stage • Sound technology • Environmental benefits • Limited stakeholder consensus
Conclusions	• Revisit stakeholders' consensus • Internalize environmental costs (local/global) • Phase out subsidies • Accelerate learning curve • International cooperation, trade key to sustainability	• Broader alliances required • Internalize env. costs (local/global) • Phase out subsidies • Accelerate learning curve (cellulosics) • International cooperation, trade for sustainability	• Broader alliances required to move out of pilot phase • Internalize environmental costs (local/global) • Phase out subsidies • Accelerate learning curve • International cooperation, including trade, a key issue for sustainability	• More focus on non-technical questions • Broader alliances to move out of pilot phase • Internalize environmental costs • Phase out subsidies • Accelerate learning curve • International cooperation, including trade, a key issue for sustainability

ETBE: ethyl ter-butyl ether
MTBE: methyl ter-butyl ether
DME: dimethyl ether
RME : rapeseed oil methyl ester.
FFV: flexible fuelled vehicle
AFV: alcohol fuelled vehicle

The focus of the most recent, ISAF XIII, in Stockholm on 3-6 July 2000 was the role of alcohol fuels in future sustainable transportation systems.

ISAF has never been formally incorporated. All work is voluntary, and there is no secretariat. Attendance at ISAF meetings has ranged from 100 to 500, depending on the level of international interest in alcohol fuels. The chair, usually from the country that hosted the latest meeting, is supported by an international organizing committee made up of key stakeholders from countries interested in alcohol fuels.

Back to the future

At the close of the meeting in July, I was asked by the Swedish organizers to summarize ISAF XIII. I proposed a panoramic view of alcohol fuels and the transition to a sustainable transportation system. From this perspective, ISAF XIII not only returned to Stockholm, where it was inaugurated in 1976, but also came back to many of the issues addressed a quarter of a century ago.

The late Gene Ecklund of the US Department of Energy, who was long associated with ISAF, attended the first meeting in 1976. At the time he pointed out that ISAF should be a forum for exchanging ideas not just among technical people, but among all relevant stakeholders.

Outside the ISAF process, a 1997 Stockholm meeting on biofuels use in transportation emphasized the need to create an international market for biofuels to move from the pilot stage to a commercially sustainable one. On this occasion, at the request of the organizers, I presented the biofuels experience of Brazil, France, Sweden and the United States[6]. It is summarized in Table 5.

Transition to sustainable transport

The transition to sustainable transport systems requires consideration of the key stakeholders and the forces driving them. Policy and actions must derive from the consensus stakeholders are able to achieve in view of these driving forces. Building up infrastructure and obtaining results should reflect stakeholders' consensus (as mentioned above), their respective driving forces, and the ensuing policies and actions.

Who are the stakeholders and what are their driving forces?

The relevant stakeholders in alcohol fuels programmes are easily identifiable for each practical situation. They are likely to include farmers, biofuels producers, the oil industry, the automobile industry, government at various levels, consumers, vehicle fleets, workers, bankers, NGOs, etc.

The driving forces comprise:

- oil supply and price uncertainties; agrifood commodity price and demand; fibre price and demand; agricultural policies (e.g. the EU's Common Agricultural Policy); non-food markets for agriproduce;
- the local and global environment (e.g. urban air quality);
- climate change;
- globalization and privatization;
- population and economic growth.

Infrastructure and policy issues

To initiate sustainable large-scale biofuels programmes, it is necessary to build up an infrastructure for such fuels' production, marketing, distribution and use. Consideration should be given to alcohol blends; neat alcohols; niche markets; broad markets; MTBE/ETBE blends in gasoline; RME and DME blends with diesel fuel; fuels' fungibility; and competition between alcohol/gasoline and RME and DME/diesel.

Policy issues to consider include:

- costs and prices of raw materials, biofuels and blends;
- subsidies/aid to investment, production and use of biofuels;
- continued research, development and demonstration (RD&D) concerning all aspects of biofuels;
- use of market niches such as government fleets;
- promotion of FFVs and AFVs;
- support for taxi/bus fleets.

Several dilemmas among relevant stakeholders reflect their driving forces. To achieve the consen-

Sustainable energy technologies: a case study of biomass gasification

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The Indian economy is continuing to grow. It requires increasing amounts of energy and generates increasing levels of CO_2 emissions. Most of the growth in India's energy consumption depends on coal, oil and gas. Delinking economic growth from intensity of resource use will necessitate major improvements in energy efficiency and substantial support for sustainable energy technologies based on renewable resources.

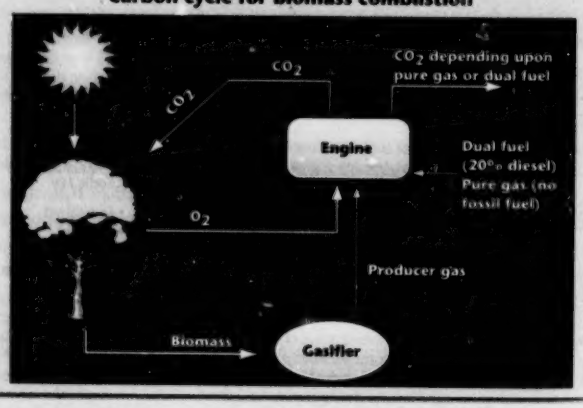
The case study of biomass gasification presented here highlights the potential for creating a network of decentralized energy services in parallel with the existing centralized structure. Quantitative indicators of the performance of *Integrated Rural Power Producers (IRPPs)* show that biomass based power units have the potential to compete with commercially available grid power while minimizing environmental impact.

Background

Developing countries must have increasing amounts of energy to meet their growing development needs, and India is no exception. Energy consumption more than doubled between 1980-81 and 1991, from 91 million tonnes of oil equivalent (mtoe) to 189 mtoe. It reached 219 mtoe in 1994-95. This figure is expected to be over 600 mtoe by 2010. Most of the energy consumed will be provided by coal, oil and gas, but energy production is also associated with greenhouse gas emissions.

Coal is a major energy source in India It provides over 60% of commercial energy requirements; and 80% of coal use is for electricity generation. Coal is also the most polluting fuel in terms of GHG emissions. Considering India's energy resources, coal may continue to provide a large part of its energy requirements in the future. India produced 651 million tonnes of CO_2 emissions in 1989, and this amount will continue to rise.[1] With the likely changes in technology leading to improvements in energy efficiency, mainly of coal and electricity use by all sectors and of oil use by the transport sector, the potential reduction in the volume of carbon emissions is as much as 200 million tonnes (compared to "no technology change") in the year 2020. The growth in carbon emissions would be lowered by 1% per year, from 5.8% to 4.8%, reducing India's contribution to global environmental pollution.[2]

Figure 1
Carbon cycle for biomass combustion



While energy consumption and demand will continue to grow, there are doubts regarding the assured supply of non-renewable resources. Most recent estimates have suggested that, at present and projected rates of production, consumption and discovery, the world's oil supply will fail to meet demand by about 2015. The long gestation period for large projects is likely to further exacerbate the supply situation.

sus needed for implementation of sustainable biofuels transportation programmes, these must be resolved. The key dilemmas are faced by the farmers, the oil industry, the automobile industry, governments and consumers.

Conclusion: the transition to sustainable transport

The emphasis in this article has been on the systems nature of the subject and the need for integration. No stakeholder alone can implement transition.

Governments are the natural initiators of actions that would bring about transition. However, before acting they should promote stakeholders' fora to generate prioritized portfolios of integrated actions. That is, while governments need to provide the vision for the transition, this vision must have the backing of the relevant stakeholders.

Driving forces have evolved over time from concerns over security of supply, to local environment and public health, to climate change concerns, and back to security of supply. The major drivers are currently local and global environmental concerns, especially in regard to climate change.

Various fuels (wood, alcohols, hydrocarbons, etc.) have co-existed throughout history. It is likely that that they will continue to co-exist in the transition to sustainable transport systems. Flexibility in every sense is crucial to the transition, as a way to reduce risk. Options must be kept open as we progress with systems' transition.

The need for new knowledge will not diminish as the transition evolves. Research, development and demonstration should continue unabated. Obviously, as markets develop commercially, RD&D will be more likely to respond. But governments must support pre-competitive research to facilitate the transition.

International agreements are needed in order to reduce risks to key stakeholders. International trade in biofuels should be part of these agreements, to address farmers' dilemmas and make biofuels truly commercial.

Once established, transition strategies should be verified from time to time with the relevant stakeholders. Enabling conditions will need to be implemented for the kick-off towards long-term competitive sustainable markets. These conditions ought to be adjusted accordingly, to reflect revised understanding among the key stakeholders.

Countries that are naturally endowed to grow food, feed and fibre to satisfy their domestic demands and the export market, and that can still either grow crops or use cellulosic raw materials and wastes for biofuels like ethanol, are good candidates for early entry into biofuels production and trade. Thus there is room to expand the liquid biofuels market and make it stable and sustainable, as suggested in many future energy scenarios. However, liquid biofuels' market penetration is likely to be limited in any future scenario on account of the many constraints and competition with other energy sources.

Notes

1. Trindade, Sergio C. (1980) Energy Crops – The Case of Brazil. In: International Conference Energy from Biomass, Proceedings. Brighton, UK, Section I, 19 pp.
2. Vergara, W., et al (1981) *Biomass Energy Production.* In: Solar World Forum – International Solar Energy Society Congress, Proceedings. Brighton, UK, pp. 1221-32.
3. Adapted from the ISAF XIII International Symposium on Alcohol Fuels brochure, 3-6 July 2000. Stockholm.
4. Trindade, Sergio C. and Walter Vergara (1995) Transportation Fuels – Ethanol Fuels in Brazil. In: *Encyclopedia of Energy Technology and the Environment.* John Wiley & Sons, New York, pp. 2707-12
5. Copersucar (2000) *Agroinndústria Canavieira (Sugarcane Agroindustry).* Mimeo, São Paulo, 14p.
6. Trindade, Sergio C. (1997). In: Cläes, Pilo, *Use of Biofuels for Transportation.* Proceedings of the International Conference, Stockholm, 29 September-1 October. ◆

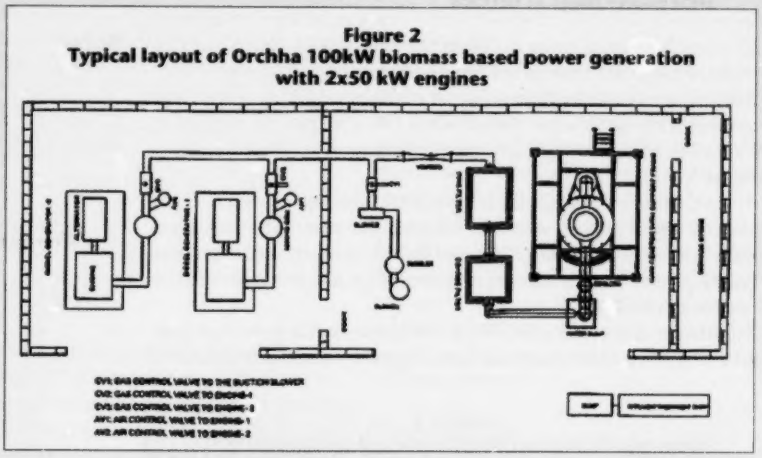
Renewable energy options

The potential for *renewable energy resources,* including hydro, solar, wind and biofuels, is tremendous. Unfortunately, in India these resources are classified as non-commercial fuels. Non-commercial fuels include wood, biomass, cow dung and biogas. Over 90% of rural households currently depend on these resources for their energy needs.

Solar energy input to the Earth is 12,000 times greater than today's commercial energy supply. Further, worldwide photosynthesis activity is estimated to store 17 times as much energy as the total consumed. Unlike fossil fuels, which take millions of years to form, biomass is a truly renewable resource. Plant life renews itself every year. Biomass energy has a bright future as a sustainable energy resource.

Biomass is organic matter produced by plants through photosynthesis. It chiefly contains cellulose, hemicellulose and lignin, with an average composition of $C_6H_{10}O_5$, with variations depending on the nature of the biomass. Biomass combustion is CO_2 neutral and biomass energy is a zero contributor to GHG emissions. **Figure 1** shows the carbon cycle for biomass combustion.

Figure 2
Typical layout of Orchha 100kW biomass based power generation with 2x50 kW engines



Biomass gasification

Theoretically, the ratio of air to fuel required for complete biomass combustion is 6:1; the end products are CO_2 and H_2O. In the gasification process, combustion is carried out under sub-stoichiometric conditions with an air-to-fuel ratio of 1.5:1. The gas so obtained, called "producer gas", is combustible. The combustible gas has a calorific value of 4.5-5.0 $MJ/_{kg}$. Its nominal composition is CO: 20%, CH_4: 3%, H_2: 20%, CO_2: 12%; N_2: 45%.

This process is made possible by a type of equipment called a "gasifier". Gasifier technology in India has been developed by the Indian Institute of Sciences (IISc) in Bangalore. The gasifier system basically comprises a reactor vessel in which gas is generated. This is followed by a cooling and scrubbing system, in which the gas is cooled and cleaned. Using producer gas, it is possible to operate a diesel engine in dual fuel mode or a gas engine in single fuel mode. Diesel substitution, in the case of dual fuel operation, is up to 85% at rated load. The mechanical energy thus derived can be used either to energize a water pump set or for electrical power generation by coupling with an alternator set. A schematic of the gasifier system, based on IISc design, is shown in **Figure 2**.

Decentralized Energy Systems India (DESI) – a case study

The strategic objective of the DESI Power Programme is to increase environmentally sustainable energy production and use, and thus catalyze sustainable livelihoods and development. The most effective way to meet rural

continued page 30 ☛

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development demands with maximum use of local resources, and without increasing carbon emissions, is to promote renewable energy technologies. The Independent Rural Power Producers (IRPPs) concept has been developed by DESI Power. Within this programme, a network of IRPPs will provide a "structured market" approach to commercialization of energy services in rural areas. Reliable power and energy services will make it possible for communities to engage in local value addition, improve community infrastructure, increase total acreage under irrigation, and enhance rural income.

Energy services being provided by IRPPs include electric power, waste energy for drying, and domestic lighting devices with portable rechargeable lanterns.

DESI power plant at Orchha

The current priority is to build IRPP power plants based on the gasification of locally available biomass materials whose supply is sustainable in the long run. Biomass materials that grow prolifically and are available as crop residues include ipomea, lantana, mulberry stalks, groundnut shells, coconut shells and cotton stalks.

The pilot plant at Orchha in central India

The first commercial 100 kW plant was set up at Orchha to supply electrical power to a paper recycling unit, a building materials production unit and a mechanical fabrication workshop, and to supply common utilities such as water pumping, air cooling and lighting. The configuration of the generation system was a 100 kWe gasifier coupled to 2 x 62.5 kVA diesel engines. Investment and generation costs are shown in Figure 3.

The feedstock for the gasifier is a locally available weed, ipomea. This is a woody type of biomass with both thick and thin stems. The thick material is sized and fed into the gasifier, and the thin stems are used to produce fuel briquettes. There is no competing use for ipomea, as it is not used for open combustion.

Operational data from the IRPP at Orchha show that generation costs are very sensitive to the plant load factor. Figure 4 provides a breakdown of operating costs in the period 1996-99. The cost of production at a plant load factor of 55% was Rs. 4.05 per unit ($ 0.09 per kWh).

Figure 3
Some typical data on investment and generation costs

Capital cost of a 100 kWe plant: Rs. 30

Specific cost: 30 000 Rs/kW

Capital costs include equipment, land and building erection and commissioning, training, project development, Project report and pre-operative expenses, two months' working capital and cash balance and contingencies.

Biomass price Rs. 400-800 per tonne (varies from region to region and site to site).

Electricity price of IRPPs of 10 kWe rating: Rs. 3-4 per kWh (with a dual fuel engine) depending on the plant load factor.

Electricity price of diesel generator set of 100 kWe rating Rs. 6-7 per kWh depending on the plant load factor. The payback period for an IRPP based on the saving and operating costs is between 2.5 and 4 years.

Electricity price for lower quality commercial and industrial loads charged by the local grids (if available): Between about Rs. 3 per kWh and Rs. 8 per kWh depending upon the state electricity board / without connection.

Ipomea: biomass with prolific growth

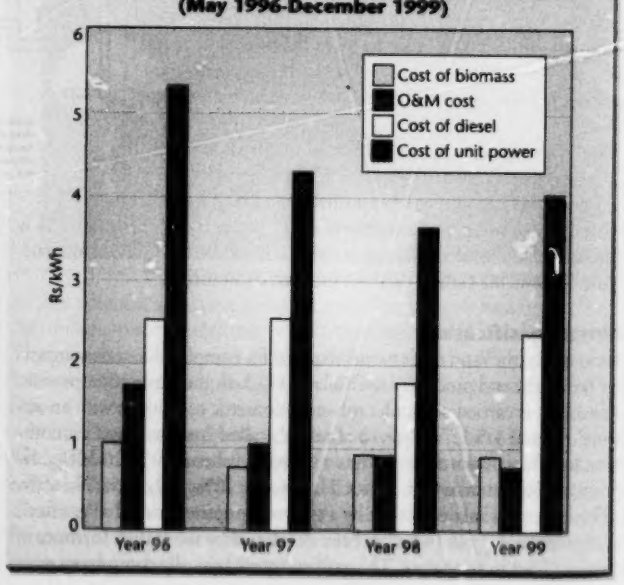
An analysis of operational plants shows that at the existing cost of biomass and under normal financing conditions, as applied to renewable energy power projects, the cost of electricity generated by biomass gasification based power plants (using diesel engines running in a dual fuel mode) is always lower than that of electricity generated by normal diesel engines running on subsidized diesel fuel. Biomass gasification based IRPPs can also compete against the commercial and industrial costs of power from the grid charged by most Indian utilities. To make a significant impact, thousands of IRPPs need to be built very year. With gestation periods of less than six months, IRPPs can multiply rapidly. Biomass availability can likewise be enhanced through captive plantations. A 100 kW plant requires only five hectares of plantation for sustainable biomass supply. The DESI Power Programme aims to convince policy-makers, investors and potential promoters that IRPPs can achieve their technical, economic and environmental goals.

Notes

1. Parikh, J. and S. Gokam (1993) *Global Environment Change*, September, pp. 276-91.

2. Painuly, J.P, K. Bhattacharya and J. Parikh (1997) *Proceedings of AIJ conference*, ed. Kalipada Chaterjee, ISBN 81-7525-043-7, p. 145.

Figure 4
Average operating costs in Rs/unit power generated (May 1996-December 1999)



Energy service company (ESCO) investments in Central and Eastern Europe

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Summary

Energy service companies (ESCOs) make it possible for customers to upgrade their facilities and reduce energy costs by investing future cash flows from energy savings. ESCOs use a type of project financing called "performance contracting": savings opportunities at a facility are identified; cost-saving measures are implemented at no initial cost to the customer; the energy savings investment is maintained for the life of the contract; and the energy savings that will be used to pay back the initial investment are guaranteed. The evolution of the North American and Western European ESCO industry has provided many lessons for Central and Eastern Europe.

Résumé

Les compagnies de services énergétiques (ESCOs) offrent à leurs clients la possibilité de moderniser leurs installations et de réduire leurs coûts énergétiques en investissant les flux de trésorerie générés par les économies d'énergie réalisées. Ces compagnies utilisent un mode de financement de projets baptisé " performance contracting " (contrats avec garantie de résultats) : identification des possibilités d'économies au niveau d'une installation, mise en œuvre de mesures d'économies de coûts sans coût initial pour le client, maintien de l'investissement axé sur les économies d'énergie pendant la durée du contrat et garantie que les économies d'énergie réalisées compenseront l'investissement initial. L'évolution de ce secteur en Amérique du Nord et en Europe de l'Ouest est riche d'enseignements pour l'Europe centrale et orientale.

Resumen

Las ESCO permiten que los consumidores mejoren sus instalaciones y reduzcan el costo de la energía, mediante la inversión de los dividendos futuros que producirá el ahorro energético. Las ESCO utilizan un método de financiación de proyectos denominado "contratación de resultados": se identifican las posibilidades de ahorro en una instalación dada; se aplican medidas para economizar, sin costo inicial para el cliente; la inversión realizada para ahorrar energía se mantiene durante la duración del contrato; y así se garantiza que la misma podrá pagarse con los ahorros resultantes. La evolución de las ESCO en América del Norte y Europa Occidental brinda muchas lecciones que pueden aplicarse en Europa Central y Oriental.

Energy conservation at the end-user level (the "demand side") is undoubtedly a key issue in all the EBRD's countries of operation. Energy intensity (energy consumption per unit of economic output) in these countries is generally three to five times higher than in Western Europe or the United States. However, technologies exist in these and other countries to reduce energy consumption significantly. Such technologies, even at current energy prices, prove very cost-effective due to the fact that the percentage of energy savings achievable is generally much higher than in similar cases in Western countries. According to all the surveys carried out by international institutions during the last 10 years, the market for these technologies could represent an investment of over ECU 50 billion.

However, realizing this potential is not easy. The main difficulty is that investments are usually very small (relative to banks' criteria) and are often to be made in the public sector: features which make it difficult for banks (EBRD in particular, but also other commercial local or foreign banks which, moreover, may have no appropriate expertise in the field concerned) to arrange direct financing.

When the EBRD decided in 1994 to set up a specialized team in charge of addressing these issues, the idea was to support the establishment and start-up of a new kind of company, unknown so far in the Bank's countries of operation although there had been over 10 years of experience with such companies in the US and Canada, where they are known as energy service companies (ESCOs), and in Western Europe, where they are called Third Party Financing (TPF) companies.

These companies are not financial institutions: they are industrial companies providing a service that can be described as "the sale of energy savings". Because they have extensive expertise and experience in energy conservation, they are able, at their own initial expense, to purchase, install and maintain for their clients the equipment needed to generate significant energy savings and to accept the risk of being reimbursed only with such savings.

Origins of the ESCO industry

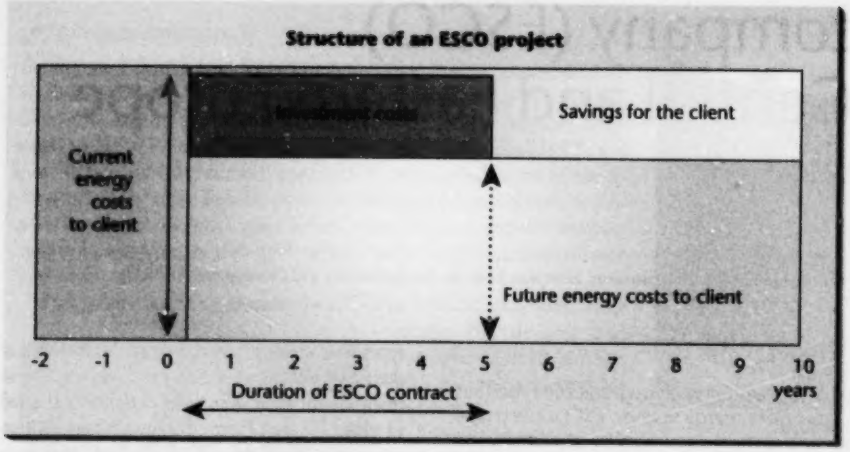
History

The ESCO industry originated as a response to rising energy prices in the early 1980s, which created both regulatory pressures and market-driven opportunities. Private investors established ESCOs to develop, install and finance comprehensive, performance-based energy savings programmes that improved the efficiency of customers' facilities, mainly buildings. ESCOs assume the risks of these projects by providing performance guarantees that tie their revenues to the amount of energy saved. As energy prices began falling in the late 1980s, ESCO-backed projects took longer to recover costs and some companies defaulted on contracts and went bankrupt.

Today, performance contracting has matured into a viable and widely accepted financing tool.[1] ESCOs have received additional impetus from the adoption of integrated resource planning by electric utilities. According to this principle, energy savings projects are recognized as new sources of energy, packaged by ESCOs and presented to utilities in competitive bids. These are known as demand side management (DSM) bidding programmes. Repayments by utilities have contributed significantly to the pool of investment capital available for performance-based energy efficiency projects.

Types of ESCOs

ESCOs can be classified as independently owned companies devoted to full-service performance contracting, and companies owned by or closely affiliated with utilities. Energy-related equipment manufacturers such as Honeywell, Landis & Gyr and Johnson Controls have ESCO services and divisions, and many regional ESCOs have grown from engineering firms and contractors. In the US today, there are at least 10 major national ESCOs. An additional 50-60 firms operate regionally. In Western Europe, ESCOs have been backed by insurance companies (Sinae in Spain), financial institutions (Econoler in Belgium, Sinerg in France), utilities (Vivendi, Lyonnaise-Suez in France, AHS Emstar in the UK) or public institutions (Idae and Icaen in Spain, SEA in Germany).


Structure of an ESCO project
Investment costs
Savings for the client
Current energy costs to client
Future energy costs to client
-2 -1 0 1 2 3 4 5 6 7 8 9 10
Duration of ESCO contract
years

Energy performance contracting

An ESCO differentiates its core business from energy consulting through energy performance contracting. This begins with designing and installing appropriate technology on the clients' premises in order to reduce energy consumption. The ESCO then provides a guaranteed level of energy savings, and of comfort or service in terms of heating or other energy related needs. The ESCO recovers its costs, together with a profit margin, from the energy savings realized over a period determined in the Energy Performance Contract (EPC).

In financing engineering, the purchase of equipment and the installation of an energy savings investment, ESCOs take two distinct approaches. Under the first approach, known as "shared savings", an ESCO assumes financing responsibility for an energy savings investment by borrowing from one or more third parties (e.g. banks, leasing companies). Under such EPCs, the customer assumes only the obligation to pay energy savings to the ESCO, which in turn repays the project debt out of these proceeds. Not only does the ESCO assume the project performance risk, but by bearing the financing responsibility for the project it assumes the customer's risk, thus providing a complete guarantee. Under such a shared savings structure, the ESCO earns higher margins from performance contracts but develops a bank-like structure leading to a declining debt/equity ratio as its portfolio of contracts increases.

The second financing approach, called "guaranteed savings", requires the ESCO to design the investment and provide an energy-saving guarantee, but leaves the client to finance the project by borrowing from a bank or leasing company as arranged by the ESCO. Typically, the ESCO's energy savings guarantee is designed to cover the customer's debt service, so that if the guaranteed savings fall short of the amount needed to service the client's debt the ESCO will pay the difference to the customer. With the guaranteed savings approach, the ESCO has no contractual relationship with the bank or leasing company. Rather, the project is financed through a commercial loan based on the customer's general credit standing, while the ESCO's performance guarantee is a form of credit enhancement.[2]

In either case, an ESCO's clients benefit in the following ways: i) they are guaranteed a reduced energy bill without any technical risk of their own (the ESCO guarantees that the payback on the investment, in the form of savings on energy bills, will service the debt and that otherwise it will reimburse the shortfall); and (ii) they take on no additional up-front financing, or if they do so they can demonstrate to their bank, shareholders and management that the debt service for this project is covered by the energy savings guaranteed by the ESCO.

Market segmentation

ESCOs typically target customers with high energy rates and bills, long hours of operation, and good credit ratings. While interest in reducing energy use and increasing productivity in industrial production processes through outsourcing of energy management is growing, this sector has proven difficult to penetrate since measuring savings at industrial sites can be problematic. Energy usage at production facilities is in part a variable cost, which is deemed to complicate the establishment of a baseline rate although concrete and proven solutions do exist. For this reason, the energy services market has been dominated by privately-owned commercial buildings and municipal facilities.

The most significant emerging market sector for energy services in the United States is currently the Federal Government, which is by far the country's single largest electricity and natural gas consumer. Market estimates for energy services in this sector are as high as $5 billion. In Western Europe, municipal buildings are the main target of ESCOs as well, although legislation favourable to co-generation has promoted ESCO-type financing of co-generation plants, particularly in Spain and Portugal.

International development of the ESCO industry

In 1994, the International Energy Agency declared its intention to support development of the ESCO industry. In the developing world, multilateral banks are increasingly supportive of the energy service company industry. Following the EBRD's lead in Eastern Europe (the EBRD is the first – and still the only – international financial institution with a dedicated Energy Efficiency Team), the World Bank has been increasingly active in establishing public sector energy service programmes in China. The IFC[3] has also shown interest in participating in some of the EBRD's ESCO deals. Elsewhere in Asia, the Government of Thailand is providing technical assistance and financing to ESCOs through the Thai national electric utility.

Implications for Central and Eastern Europe

The lack of available financing from local banks, the small size of an average project, and the relatively rapid payback on energy savings investments makes the shared savings performance contracting model useful for Eastern Europe. The EBRD has led the way in financing and structuring the nascent ESCOs involved in performance contracting in the countries of the former "Eastern Block", mainly in conjunction with Western utilities or equipment manufacturers. It has signed four framework agreements (so-called "Multi Project Facilities") with Dalkia, Landis & Gyr, Honeywell and MVV to develop such ESCOs. EBRD-sponsored ESCOs to date are majority-owned and operated by private sponsors with both the necessary expertise and experience in the ESCO business and financial strength to guarantee the Bank's debt, usually with some carve-outs. Fourteen of these ESCOs are now operating in Hungary, Slovakia, Poland, the Czech Republic, Lithuania and Romania. The EBRD has also financed a state-owned ESCO in Ukraine, operated by a European ESCO. In addition, ESCOs founded by local entrepreneurs in Hungary, Poland and the Czech Republic are becoming a competitive force.

The ESCOs' expanding role in restructuring the energy sector in the West underscores their importance in Eastern Europe, as they lead the way in rationalizing and decentralizing the thermal and electrical energy infrastructure and have a key role in reducing CO_2 emissions. ESCOs are increasingly involved in designing and financing heat and power co-generation plants supplying industrial and municipal consumers with low-cost energy.

While the region is in many ways well suited to the energy service industry, it presents particular challenges for performance contracting. Prerequisites for building a successful portfolio of performance contracts include the following:

Successful evaluation of creditworthiness

An ESCO must be able to judge long-term commercial risk for municipal, industrial and commercial customers. While rapid payback rates mitigate these risks, they will vary broadly among countries. For example, none of the ESCOs in Hungary with which the EBRD is in contact has experienced any performance contract defaults so far.

Cost-effectiveness

Performance contracting is a sophisticated, long-term financial transaction. Calculating potential savings benefits requires calculating the cost of

money over time, including future inflation and interest rates, as well as the development of future energy prices. This information is unpredictable in transition economies. Mitigating the uncertainties in these calculations is the high probability of rising energy prices throughout the region, as well as the strong potential for energy savings as antiquated infrastructure and production facilities are restructured.

Supportive utilities

Utilities could have a major impact on the growth of the ESCO industry in the region. Their support hinges on commercial incentives to support energy savings projects despite the implied loss of revenues. On balance, utilities appear to be potential allies in the region as they undergo deregulation. Utilities in Hungary, nearly all Western-owned, are tentatively in favour of demand side management when it allows them to i) secure their customer base, ii) shift peak loads, thus delaying capital investment in transmission and distribution, and iii) create political goodwill. These distribution utilities may well wish to work with privately-owned ESCOs that enable them to support ESCO projects meeting the above criteria.

Engineering accountability

Performance contracting requires a new level of technical competence that may not be readily available in the East. ESCO engineers must be able to calculate all implementation costs and potential savings. The engineers must also be able to assess organizational commitment at every management level within the customer's organization.

Conclusion

The ESCOs working in Eastern Europe have already demonstrated that all the above issues can be addressed adequately. Investing in ESCOs prepares the path for private capital in the energy services industry throughout the region, and paves the way for significantly reducing these countries' energy consumption and level of pollutant emissions.

Using performance contracting, ESCOs are in a uniquely position to help companies in Eastern Europe decrease energy consumption, thereby improving their competitiveness, reducing macroeconomic dependence on imported fuel, and reducing CO_2 emissions. With energy market deregulation and rapid price increases, the investment capital and engineering expertise to implement energy savings projects is on the rise in Eastern Europe. However, CIS countries are still considered generally too risky to attract private capital despite many the energy savings opportunities.

Both the indigenous and Western-owned ESCOs operating in EBRD's countries of operation are increasingly experienced in evaluating and minimizing commercial risk. Having begun with heating and lighting investments for municipalities, ESCOs are now breaking new ground that enables them to move on to residential, commercial and industrial customers. As privately-owned ESCOs emerge to provide energy efficiency services to the same market sectors served in the West, investment capital from the EBRD and others can be profitably employed to provide energy services to the region.

Over 20 ESCOs are developing a sound business in the countries of Central and Eastern Europe, among which 15 were initiated by (and set up with the financial support of) long-term loans and equity participation provided by the EBRD. So far, more than Euro 600 million has been committed by the EBRD and its partners to developing these ESCOs, leading to the realization of dozens of energy saving investments in schools, hospitals, municipalities, prisons, barracks, railway stations, industrial and residential premises, etc. On average, these investments have generated energy savings and greenhouse gas emission reductions of over 35%.

Notes

1. Honeywell alone reported $500 million in sales of Energy Performance Contracts in the United States in 1996.
2. ESCO projects in the United States have been financed by debt using guaranteed savings contracts, whereby the customer secures long-term financing (seven to 15 years) for an energy efficiency investment from a bank or leasing company, or from a utility in the form of a rebate of a subsidized loan. Municipal leases, which are the least expensive and the commonest form of lease financing, are used to finance projects in schools, hospitals and other facilities. The average installed cost per project ranges from $500,000 to $2 million. While this performance guarantee can act as a form of credit enhancement, it is not a guarantee of payment, as the bank looks to the customer for underlying credit.
3. The International Finance Corporation (IFC) is a member of the World Bank Group (ww.ifc.org).◆

Sustainable energy

Integrated Electricity Planning in Southern Africa

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Summary

This article summarizes the Integrated Electricity Planning (IEP) process, in the context of the 12-country Southern African Power Pool. Use of IEP for long-term planning is described. The article also focuses on decision-making concerning future capacity. Roles and measures that could facilitate the adoption of cleaner technologies in Southern Africa are presented.

Résumé

L'article présente dans ses grandes lignes le processus de planification intégrée de l'électricité (IEP) dans le contexte du Pool énergétique de l'Afrique australe qui regroupe 12 pays. Il décrit l'application de l'IEP à la planification à long terme. Il met également l'accent sur les décisions qui devront être prises à propos de la capacité future. Enfin, il présente les mesures susceptibles de faciliter l'adoption de technologies plus propres en Afrique australe.

Resumen

Este artículo resume el proceso de Planificación Eléctrica Integral (PEI) en el contexto de los 12 países que participan en el Southern African Power Pool (Comunidad Energética de África Meridional). El texto describe cómo el PEI hace posible la planificación a largo plazo. Asimismo examina la toma de decisiones acerca de la capacidad futura. También plantea los cometidos y las iniciativas que podrían facilitar la adopción de tecnologías menos contaminantes en la región.

The entire African continent accounts for a mere 3% of total world commercial energy consumption. Energy starvation is widespread, exaggerated by frequent droughts and floods, restricting the availability of biomass and hydro resources. In addition, power transmission and distribution grids are poorly developed and typically are not integrated.

With respect to electric power, 76% of Africa's capacity is thermal, with oil and natural gas predominant in North Africa and coal and oil predominant in Southern Africa.[1] Access to power grids is a major challenge in Africa. Electrification rates are extremely low in many areas – particularly rural ones.

The electricity sector in Southern Africa is largely coordinated via the Southern African Power Pool, an interconnected system covering 12 nations in the Southern African Development Community (SADC). The SAPP has as its vision a "competitive Southern African wholesale market in which the production, delivery and exchange of bulk, electrical energy is coordinated, operated and developed at world class standards and with minimum impact on the environment."[1]

Among the SAPP's objectives are:

- to coordinate the planning and development of interconnections between members' respective networks, in order to expand the Interconnected Power System and electricity trading in the region;
- to reduce investments and operating costs, enhance reliability of supply, and share in the benefits resulting from coordinated planning and operation of the interconnected power system;
- to coordinate the planning, development and operation of generation and transmission facilities in their respective networks with minimum impact on the environment.

Balancing these objectives is the subject of this article. Integrated Electricity Planning is a powerful tool for business planning and environmental management. The article describes the process and indicates a potential direction for the Southern African Power Pool, based upon the planning process currently under way (**Table 1**).

Integrated electricity planning process

Integrated Electricity Planning is defined as that process which selects, from a full array of demand and supply side options, the combination of actions, risks and investments which:

- satisfies customers' electricity needs;
- achieves optimal value for the customer;
- is financially viable for a utility;
- is compatible with the utility's strategic direction.

Essentially, IEP is aimed at optimal utilization of resources. This is achieved by balancing supply and demand side processes in an optimized manner. The process followed in developing the plan is described in **Figure 1**. The strategic foundation for planning includes:

- reliability and reserve criteria for optimization studies;
- main planning criteria and assumptions;
- main environmental management constraints;
- supply and demand side data;
- risks and uncertainty;
- optimization criteria.

The base case that defines the current situation is then established, taking into account existing trading contracts as well as transmission and environmental constraints. A "business as usual" demand and load forecast is prepared. A current forecast is as shown in **Table 2**.[2]

Different scenarios which aim at optimizing generation capacity additions without trading limitations or transmission constraints are then developed. These scenarios are essentially different pictures of the future. They would typically consider variables such as:

- electricity demand;
- environmental constraints;
- plant availability, especially as impacted by drought;
- specific national priorities.

A discounted cost analysis is undertaken for each scenario. This includes capital, fixed and variable costs (i.e. operating, maintenance and fuel costs).

The different scenarios and results are analyzed against least-cost criteria. The best plan or plans are identified. Environmental issues, threats and opportunities are evaluated, as are risks and uncertainties associated with the plans. Based on this evaluation, a decision-making framework is defined for consideration by all utilities.

The balance of this article focuses on the important factors utilities need to include in this decision-making, with a focus on environmental considerations, constraints to the uptake of environmentally benign technologies, and the role of policy-makers in accelerating the uptake of such technologies.[3]

Important factors in capacity choice

The choice of technology for future capacity is guided by numerous decision-making factors. In approximate order of importance, these are:

- capital and operating cost;
- plant reliability and availability;
- access to indigenous low-cost fuel;
- lead times;
- operational flexibility (base load versus peaking, etc.);
- water availability;
- environmental considerations (likely to move up in order of importance with time);
- security of fuel supply;

- local capacity to sustain technology (skill, infrastructure, etc.);
- funding availability;
- political considerations.

Environmental considerations

Environmental considerations play an extremely important role in planning expansion. However, in the SAPP this role is at a far more operational level than in developed nations. The focus is on local and regional environmental impacts and benefits, with lower priority being given to global impacts. For example, introducing low-smoke coals to reduce urban air pollution will in effect increase CO_2 emissions due to the energy required by the devolatilization process, as well as the product's lower energy content.

The primary environmental issues are presented with a South and Southern African perspective below.[4] It should be noted that the attention given to environmental matters in the region varies considerably from country to country.

These issues clearly receive varying attention as components of environmental impact assessments on a project by project basis:

Water quality and availability

Availability of water is one of the critical environmental issues in Southern Africa. Water supplies are highly variable, in terms of both quality and quantity. Technology choices are often strongly influenced by the amount of water used, as well as the impact on water quality.

Land management/ecological impacts

While land is generally readily available, the ecological impacts of a particular technology require assessment, especially in areas where eco-tourism is an important consideration. The inundation of land by hydro projects is an issue requiring particular attention.

Air quality

Power plant emissions receive varying degrees of attention. In general, a holistic approach is adopted with respect to air quality. In South Africa, air quality is assured via use of a "best practicable means" approach. This implies that primary attention is paid to particulate removal, and then the impacts of SO_x and NO_x are managed via ambient air quality requirements. The Department of Environmental Affairs and Tourism is currently investigating this management process. Acceptable air quality levels are maintained through combustion of low sulphur coals and tall stacks.

It should be noted that extensive research into air quality has been undertaken in the main South African power generation region, Mpumalanga, over a 15-year period. This research has clearly demonstrated the efficacy of the current air quality management processes in maintaining local and regional air and rain qualities at acceptable levels. Air quality has improved by an average of 4% annually for the last ten years, greatly allaying concerns related to exceedance of local and regional air pollution standards. WHO levels for ambient air quality are rarely exceeded.

Waste management

Production of waste, especially large quantities of fly ash from the combustion of high ash coal, requires careful management. An important component of technology assessment is ash disposal and utilization and the rehabilitation of disposal sites. In addition, the water used in waste transport and disposal is an important consideration in technology choice.

Socio-economic impacts

Socio-economic development is the highest priority in the region. The choice of a supply side option and the attendant environmental controls is strongly dependant on impacts on society as a whole. For example, if it is a matter of choosing between utilization of resources for an electrification programme versus fitting additional pollution control equipment, where such equipment is an environmental luxury, then the former has precedent. The term "environmental luxury" implies a "nice to have" that is not justified on scientific or economic grounds. This example is well-illustrated in South Africa where, due to the combustion of low sulphur coal coupled with tall stack dispersion, air and rain quality levels in the vicinity of power generation are maintained at acceptable levels. The motive for installing additional environmental controls (e.g. desulphurization) is therefore limited, especially when one considers the alternative application of resources. In particular, it has been shown that in the long term electrification of urban areas results in significant reduction of currently unacceptable pollution levels due to domestic combustion of coal. In this regard, electrification may be regarded as a clean coal technology.

It should be noted that a significant percentage of people (some 70%) are unlikely to get rid of their coal stoves in the short to medium term even after electrification. Therefore, in the interim (medium term) an integrated approach of continued electrification, fuel optimization (low-smoke fuel and combustion appliance improvement) and housing energy efficiency (insulation) is encouraged in order to reduce unacceptable urban residential air pollution levels.

Ecologically sensitive areas

Routing transmission lines through ecologically sensitive areas is the subject of comprehensive environmental impact assessments in most countries in the region. Some projects to increase other countries' capacity to undertake such studies are currently under way. Soil erosion can be a particular problem, as can the ecological impact of structures and lines, especially on wildlife such as birds.

Global impacts

As these are developing nations, the issue of CO_2 emissions from generating plant is given relatively limited attention. The approach typically adopted is one of striving to improve plant efficiency, reliability and availability, with attendant CO_2 emission reduction benefits. There is little motivation to select a technology that produces less CO_2 merely for the sake of it, or at a cost premium.

While policies are still being formulated, it is considered that if full incremental costs were covered by developed nations, CO_2 emission technologies could be viewed with more favour.

Potential developments

Some potential developments in Southern Africa between now and the year 2015 are:

- Industry restructuring will play an important role during the next five years, especially in South Africa;
- Environmental pressures, regulations and requirements will increase;
- The Southern African Power Pool will play an important role in balancing supply and demand;
- Natural gas may be used for power generation;
- Coal and hydro will continue to be the main sources of primary energy for power generation;
- Clean coal technologies will only be introduced once increased capacity is required, and if they meet cost and reliability criteria.

Barriers to introduction of advanced power generating technologies

Clearly the most significant barrier to the uptake of advanced, environmentally benign power generating technologies in Southern Africa is the region's current excess generating capacity, coupled with generally energy intensive economies and a significant potential for financially viable demand side measures. It should be noted that projections of economic growth in the region are highly variable, with "aspiration figures" as high as 6% being quoted. Given the fact that economic growth and growth in electricity demand are still directly correlated, a 6% growth rate would create the need for major capacity expansion (up to 2300 MW per year) from the year 2004. This clearly offers immense opportunities for economically competitive cleaner technologies.

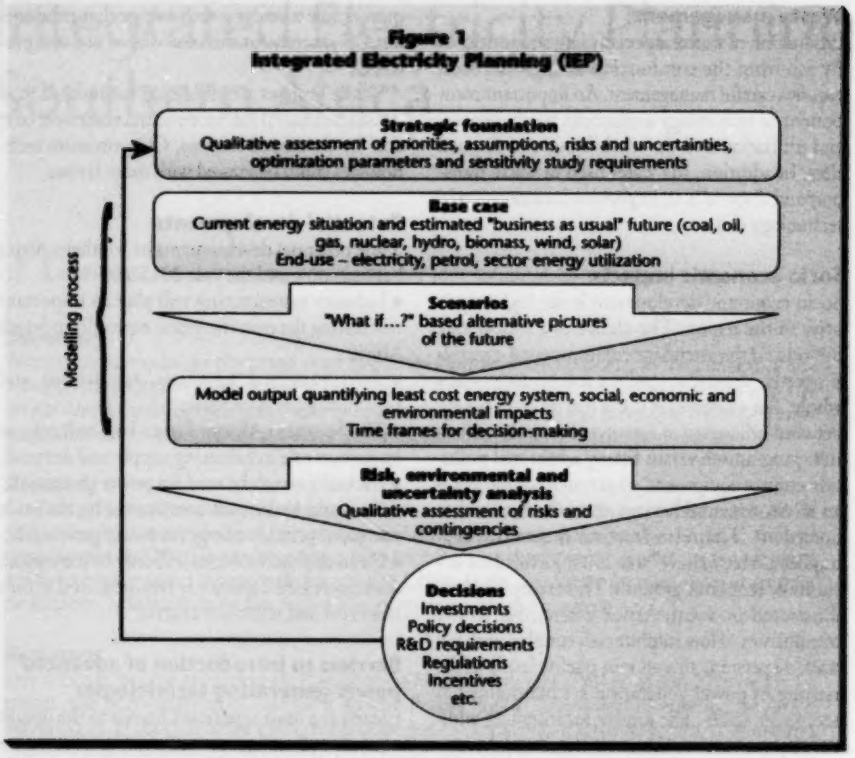
If one assumes such opportunities, other potential barriers to the introduction of these technologies must be considered. These include:

- perceptions of advanced technologies' unreliability and high operating costs;
- limited local skills to adapt to new technologies;
- limited support infrastructure to cater for new technologies;
- competition from other technologies and fuels such as hydro, gas and possibly nuclear;
- the need to assess performance in a Southern African environment, e.g. combustion of local low grade coal, etc;
- the relative efficiency of current plant (an average 34.4% in 1999).

It is considered unlikely that new technologies will displace existing plant, especially given current plant efficiencies.

The relatively young age of current operational coal fired power stations in South Africa (11-15 years) precludes their upgrading to clean coal technologies (CCT) without efficiency or water consumption penalties. It is therefore necessary for CCT to replace this plant upon decommis-

Figure 1
Integrated Electricity Planning (IEP)


Strategic foundation
Qualitative assessment of priorities, assumptions, risks and uncertainties, optimization parameters and sensitivity study requirements
Base case
Current energy situation and estimated "business as usual" future (coal, oil, gas, nuclear, hydro, biomass, wind, solar)
End-use – electricity, petrol, sector energy utilization
Scenarios
"What if...?" based alternative pictures of the future
Model output quantifying least cost energy system, social, economic and environmental impacts
Time frames for decision-making
Risk, environmental and uncertainty analysis
Qualitative assessment of risks and contingencies
Decisions
Investments
Policy decisions
R&D requirements
Regulations
Incentives
etc.
Modelling process

sioning, or to penetrate the growth market. CCT could also replace older plant now in mothballs.

It should be noted that the current South African practice of burning low-grade (high ash, low sulphur) coals for power generation results in extremely low primary energy costs. This makes it difficult for competing technologies utilizing other fuels to penetrate the power generation market – as they are two to three times more expensive on life cycle costing. Clearly CCT combusting low-grade coal, with more favourable capital costs and efficiencies, will receive serious consideration as replacement plant.

Southern Africa's major energy resources are coal and hydro. Outside South Africa, the focus in the region will be on hydro development. Individual national priorities and non-optimal commercial attitudes, however, can act as obstacles to this development.

Political issues are considered to present a minor to non-resistant barrier to the introduction of cleaner technologies. Resources, especially funding, are often major constraints in any supply side option in Sub-Saharan Africa. Innovative funding options/aid packages are therefore required.

Accelerating adoption of cleaner technologies

In assessing the options open to governments and industry for facilitating rapid uptake of cleaner technologies, it is assumed that the need for additional or replacement capacity exists. This is clearly not the case in Southern Africa, given the current excess capacity potential for demand side measures. Nevertheless, some ideas from the perspective of a developing nation are presented below.

Catalyzing economic growth

In a Southern African context, it is obvious that economic growth is an important driver with regard to increased electricity demand – which is an obvious precursor of the uptake of cleaner technologies once excess capacity is exhausted. International trade protocols and avoidance of discriminatory trade practices, especially on environmental grounds, are critical considerations.

It should be stressed that catalyzation of economic growth in developing nations by governments and industry is no guarantee that cleaner technologies will be adopted to meet electricity demand. Numerous selection criteria (as detailed above) will be applied. Some of the following measures are proposed to enhance cleaner technologies' appeal in the selection procedures.

Application of the UN Framework Convention on Climate Change

Two of the most important criteria when power generation technology is selected are cost and reliability. In this regard, developing nations feel the UNFCCC should be far more rigorously applied by the governments of developed nations in meeting the full incremental costs of cleaner technologies over current conventional technologies. If this involves additional costs of redundancy to ensure reliability levels equivalent to current plant, then such costs should also be covered.

It is not considered appropriate or equitable for the governments of developing nations to fund the "premium" costs of cleaner technologies aimed solely at meeting UNFCCC objectives.

In addition, current negotiations around the Kyoto mechanisms should include an assessment of the potential for cleaner technologies to be used as future CDM projects.

Research, development and demonstration

While it is accepted that virtually all cleaner technologies are at or beyond the advanced pilot or demonstration stages, it is essential that such programmes be undertaken in a variety of countries. The perceptions around costs, availability and reliability will only be addressed if pilots are undertaken in the countries of final application, especially developing ones. This will also enable the technologies to be tailored to meet unique local conditions and develop enabling capacity for ultimate application. Incentives for cleaner technology pilot plants in developing nations should be developed.

Technology transfer

In most countries, especially developing ones, current technological infrastructure and capacity are aligned with current technologies. The skills available to develop parallel capacity in new technologies are limited. It is suggested that intensive technology transfer programmes be entered into to develop this capacity. Technology transfer from developed to developing nations should include consideration of:

Table 1
The SAPP countries

Country	Utility	Installed capacity (MW)	Maximum demand (MW)	Sales (GWh)	Sales growth (%)
Angola	ENE	598.1	209	1009	-
Botswana	BPC	132	256.4	1478.7	8.02
Lesotho	LEC	-	-	-	-
Malawi	ESCOM	243.1	190.2	802	5.6
Mozambique	EdM	213.2	235	885.4	16.5
Namibia	NamPower	393	292	1812	-1.03
South Africa	ESKOM	37,848	27,803	171,454	-0.6
Swaziland	SEB	50	145	695	3.4
Tanzania	TANESCO	591.1	367.52	1823	18.6
Democratic Republic of Congo (DRC)	SNEL	2360	993	3312	-14
Zambia	ZESCO	1632	1126	6430	3
Zimbabwe	ZESA	1960	1950	10,162	-2

Table 2
A "business as usual" forecast

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Maximum demand (MW)	32,117	35,013	36,264	37,673	38,556	39,662	41,050	42,316	43,581	44,873	44,977	46,189	47,626
Energy sent out (GWh)	198,849	207,285	213,486	221,356	226,421	233,033	239,635	246,785	254,193	261,570	269,094	276,259	283,908

- funding;
- long-term training in the receiving nation;
- development of a technological support infrastructure;
- technology adaptation to local conditions;
- life cycle funding.

It should be stressed that technology transfer must be applied in the most holistic sense possible. It is necessary to have systems in place that support the technology during its life cycle, not merely to the commissioned stage. The ongoing capacity-building component of technology transfer is therefore a critical success factor.

Costs, availability and reliability

For new technologies to penetrate the market, they must clearly demonstrate business advantages over current technologies. In this regard, efforts to reduce costs and improve availability and reliability should be intensified. It is considered that advanced technologies must demonstrate significant advantages over current technologies before being widely applied in developing nations. Here the pilot programmes mentioned above could have an important role to play.

Direct intervention

Governments in developing nations are often the main catalyst for new energy development, as motivated by a variety of political factors. It is rarely driven by economic considerations. Direct intervention is obviously a potential mechanism to increase the speed of application of cleaner technologies, but it is generally non-sustainable in economic terms, especially where excess capacity exists.

Development of human capacity

In many utilities in developing or underdeveloped nations, significant efficiency improvements are possible via effective application of current technologies, i.e. what is already in place. More attention needs to be given to training skilled technical and managerial personnel. In particular, organizational skills for initiating and managing inter-utility projects across national boarders in particular need to be developed. Greater local availability of such skills would be extremely useful in optimizing efficiencies in regions like Southern Africa.

Notes

1. US Department of Energy (1999) *Energy in Africa*. Energy Information Administration, Washington, D.C.

2. SAPP Annual Review Report (April 1997, March 1999). ZESA Printshop, Harare, Zimbabwe.

3. International Energy Agency (1998) *Regional Trends in Energy-Efficient, Coal Fired Power Generation Technologies*. OECD, Paris.

4. Lennon, S.J. and J. DuToit (1995) Energy and the Environment in Southern and East Africa, *Journal of Energy in Southern Africa*, Vol. 6, No. 1, February, pp. 43-46.

Prospects for developing renewable energy in Africa

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Summary

Development of renewable energy technologies can help improve living conditions in Africa's arid, semi-arid and sub-humid regions. Renewable energy would increase these regions' energy autonomy and more effectively address desertification. As Africa looks at ways to carry out needed technology changes, it is likely to find some Asian countries' efforts to meet growing energy requirements especially useful. Possibilities for cooperation between Africa and Asia in this area have not been adequately explored.

Résumé

La généralisation de la technologie des énergies renouvelables est une des voies possibles pour améliorer les conditions de vie dans les régions arides, semi-arides et sub-humides d'Afrique. En effet, l'emploi de sources d'énergie renouvelables permettrait d'accroître l'autonomie de ces régions sur le plan énergétique et de lutter plus efficacement contre la désertification. Confrontée à une nécessaire évolution technologique, l'Afrique pourrait faire son profit des efforts de certains pays asiatiques pour répondre à la demande croissante d'énergie. Dans ce domaine, les possibilités de coopération entre l'Afrique et l'Asie sont loin d'avoir été pleinement explorées.

Resumen

El desarrollo de tecnologías energéticas renovables puede contribuir a mejorar las condiciones de vida en las zonas áridas, semiáridas y semihúmedas de África. La energía renovable aumentaría la autonomía energética de estas regiones y atacaría de modo más eficaz el problema de la desertización. Ahora que África busca la manera de realizar los cambios tecnológicos que necesita, es probable que encuentre particularmente útiles los esfuerzos que algunos países asiáticos han llevado a cabo para satisfacer la demanda creciente de energía. El potencial de cooperación entre África y Asia en este ámbito no se ha explorado todavía de manera apropiada.

Significant disturbances during the last few decades have hit the ecosystems of arid, semi-arid and sub-humid regions with particular force, provoking or accelerating desertification. This has had many appalling effects. Desertification spreads poverty. And it often causes or increases insecurity and instability, especially for the many rural inhabitants compelled to migrate to cities. Too often entire peoples are relegated to the status of ecological refugees. This situation engenders intense pressure on scarce natural resources (water, land, biomass, etc.). The living conditions and development prospects of populations living in severely stricken areas are becoming ever more tenuous.

African countries in these regions have many difficulties to contend with. Among the most urgent is how to supply energy requirements. Energy is fundamental to fulfilling basic needs (water, food, health, education, etc.), fuelling economic and social development, and, not least, combating desertification. To a certain extent, the level of energy consumption reflects a region's level of development. Africa's per capita energy consumption is the world's lowest, and traditional biomass use continues to dominate.

If Africa is to achieve social and economic development in keeping with its demographic growth during the years to come, energy consumption must soar. Among the most important questions of our epoch is therefore: How (according to what modalities, at what rate, and taking advantage of which alternatives) should this essential increase take place? What are the foundations of "sustainable" energy strategies that are economically viable, environmentally sound, socially equitable and institutionally coherent? What lessons from Asia's energy transition experiences could be helpful for Africa? Could cooperation with Asia meaningfully help develop strategies that would be more appropriate to African societies?

Characteristics of rural energy use in Africa

Despite local and regional differences, rural Africa has many general characteristics that influence its approach to energy development. In addition to heavy dependency on biomass, there is limited use of "modern" forms of energy and a generally low level of energy consumption. Energy demand in rural areas is decentralized and dispersed. Low income levels, lack of qualified labour, and socio-political and economic instabilities are key constraints limiting any prospect of improvement in the short and medium terms.

As in other parts of the developing world, most Africans live in rural areas. They are mainly farmers or herders, depending upon where they live. Production systems, which are generally extensive, are part of subsistence operations with low productivity. Conditions in rural areas are sufficiently hostile that migration to urban areas is common and is increasing. Demographic growth and climate-related factors will certainly cause this trend to intensify.

To meet domestic energy requirements, rural populations use various forms of biomass almost exclusively (e.g. fuelwood, agricultural and animal wastes). Because of their heavy dependency on biomass, rural populations are forced to overexploit their natural resources and agricultural wastes. In some areas this occurs at the cost of soil fertility. Rural energy practices, coupled with non-intensive production systems and inefficient energy habits in large parts of urban and suburban areas, aggravate natural degradation through deforestation, soil erosion, etc.

Modern energy sources, generally kerosene and occasionally electricity, are used mainly for lighting. Other uses are only marginal. Production activities, notably agricultural ones, consume relatively little energy since they rely primarily on human and/or animal power. Extension of the electricity grid to rural populations is often compromised due to the high level of investment required, which is unprofitable owing to low income levels and low population densities. Grid connections frequently do not exceed 25% of village households.

These characteristics of rural Africa call for original and innovative solutions. While per capita income in Asian countries (particularly India and China) is low, these countries do not have the same problems as Africa; they have higher population densities, and the marginal cost of installing electricity networks is lower.

Is renewable energy a credible alternative?

Due to their geographical situation, arid, semi-arid and sub-humid regions are endowed with immense solar potential. Some are also conducive to harnessing of wind power. Given the dispersion of rural communities and recent developments in renewable energy technology, decentralized exploitation would be the best strategy. A policy for developing renewable energy (wind and solar)

would help to improve the living conditions of people in these regions, and to increase their energy autonomy and tackle desertification much more effectively. It is also reasonable to hope that in a few years wind energy could make cheap desalinization of brackish water possible.

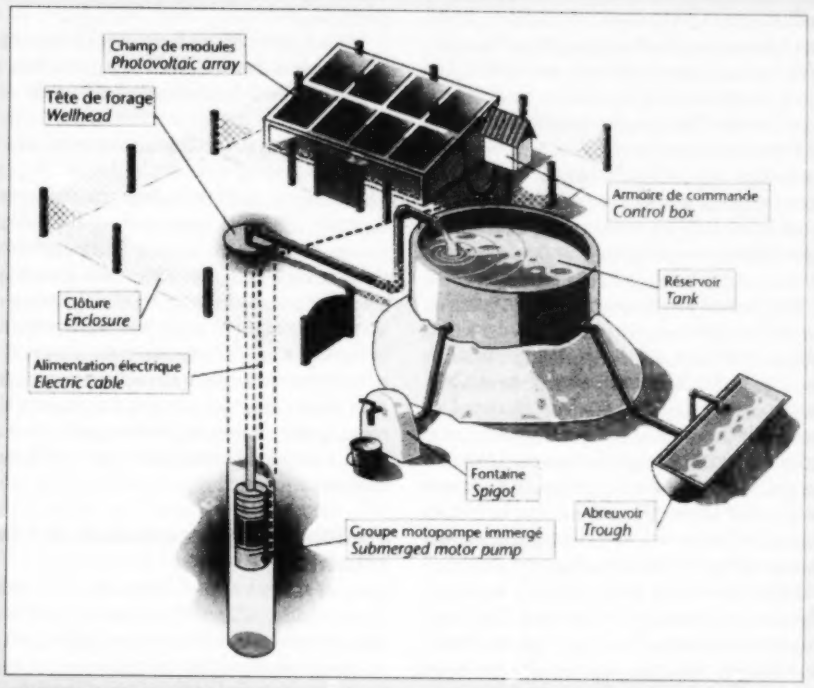
Today we are witnessing spectacular development of renewable energy. The range of applications is continuously growing. Numerous experiments have been carried out with a view to adapting these technologies to the socio-economic conditions of different areas. Many areas are still deprived of electricity supply on account of their remoteness from conventional energy systems. In such a context, it is clear that decentralized generators are crucial to their development. Photovoltaic systems cater to most important local demand for low-tension electricity (less than 220 kW) and, in rural areas, for village water supply, irrigation of small market gardens, and community amenities (health, telecommunications, educational establishments, etc.).

Although less extensively applicable than solar energy, given the right conditions wind power can make a considerable contribution to satisfying the needs of arid areas. Notably, it has enabled populations in many areas to harness water supply for agriculture and cattle. Wind power technologies that require mechanical expertise are still quite simple and easy to maintain. Aero-generators offer the same advantages as solar panels. Expected advances in wind power technology could make this a very important way to generate electricity, albeit one restricted to a few suitable regions.

All over the world, including in various arid, semi-arid and sub-humid regions, there have been numerous concrete successes (e.g. a CILSS regional solar programme that installed 1300 photovoltaic pumps in the Sahel region;[1] the development of solar lighting systems benefiting 60,000 households in the developing world; solar television in Niger). These have provided the wide range of applicability and the effectiveness of the technology for exploiting wind and solar power.

Despite all the advantages of alternative energy forms, and the role they can play in the struggle against desertification, they are still not exploited to the extent they should be. Indeed, they suffer from a lack of genuine and sustained attention. Moreover, the multiplicity of initiative- and decision-taking centres, and the dispersal of projects that results, militate against formulation of a coherent and focused alternative energy development policy. In many poor regions, the use of alternative energy sources is still regarded as merely experimental. In implementing the majority of projects, only technical aspects are considered truly important. This is primarily because they cost too much under present conditions. There is no operating framework for developing alternative energy sources appropriate to Africa's social, economic and political contexts. To significantly increase the share of renewable energy in meeting basic energy needs, and to implement strategies to fight desertification, it is essential to fundamentally re-think energy policies in most of those countries severely stricken by aridification and desertification.

Photovoltaic electricity



A photovoltaic cell uses the properties of semi-conductor materials to transform light directly into electrical energy. When it receives a photon flux (solar radiation), this cell can be considered a source of variable current with a fixed voltage. Cells are connected and assembled into a module. The resulting product, robust and hermetically sealed, usually has an area of 0.5m² and produces 50 W of power with a chosen nominal voltage. A generator devoted to a given application is made up of series-connected and parallel-connected modules. An inverter is used to get AC current. Such a solar photovoltaic generator may then feed, for example, the electric motor of a centrifuge pump immersed in a well; the pumped water accumulates in a tank and is then directed to a spigot or trough. When the generator supplies lamps, refrigerators or TV sets which operate at night, the power produced during the day must be stored in a battery.

New policies should incorporate the following elements:

- systematic study of the possibilities for exploiting alternative energy sources in national infrastructure programmes (village waterworks, health, irrigation, etc.);
- reformulation of the norms used to analyze demand for (and production and distribution of) energy. This aspect is particularly relevant to the issue of rural electrification, and of how to harness national producers and distributors of alternative energy in this sector;
- fiscal and tax incentives concerning products and services related to exploitation of alternative energy sources, to encourage initiatives;
- greater consultation, so as to implement a regional programme at all levels of development of the different strands (research, pilot actions, distribution);
- drawing up of financial modalities for local authorities, associations and individuals, in order to obtain medium-term loans to fund basic equipment;
- strengthening of local expertise with alternative energy technologies, through establishment of indigenous research and development centres and support for private initiatives to manufacture and install supply services, so that national markets that are too derestricted are decompartmentalized and regional cooperation is enhanced.

Biomass as an energy source

At the beginning of the 1980s, the international community identified rational use of firewood and biomass for cooking and heating as one of the energy sector's major priorities in many developing countries. This was in light of the fact that forest resources have often suffered from excessive exploitation, with damaging ecological repercussions and serious firewood shortages. Severe problems of erosion, accumulation of silt, and desertification are already affecting arid, semi-arid and sub-humid regions. Without adequate solutions in the foreseeable future, more people than ever before will (for various reasons) continue to rely on fuelwood to meet their basic needs. Traditional tools, which most of these people use, are often quite crude and produce low yields. A number of measures have been taken to encourage rational use of biomass energy resources, notably:

- increasing the productivity of current fuelwood resources;
- creating new forestry resources;
- preliminary treatment of fuel;
- organization of fuelwood distribution;
- perfection and adoption of improved stoves;
- taking advantage of possibilities for substitution by other forms of biomass or weak fuels, etc.

Distribution of improved stoves

Relatively sizeable means have been employed by various concerned groups and bodies to implement these measures. Even though precise results of all the actions undertaken are not yet available, it is clear that the same problems exist despite these actions. Given present conditions, it would be folly to advocate pursuing the same measures on the same scale to benefit the poor majority. On the other hand, it would be realistic to distribute more extensively improved stoves, especially in cities. Neither the technology nor the distribution of improved stoves is anything new.

Distribution programmes have been going on for nearly half a century (they were launched around 1940 in Asia), and particular effort has been devoted to them over the last 30 years. Originally these programmes were intended to improve living conditions. Later they were part of "appropriate technology" campaigns. Now they are part of energy and environmental preservation policies. All these efforts combined have been marked by hesitation, stagnation, and rearrangement of technical choices and target populations.

There have been many failures, especially regarding distribution programmes in rural areas, mainly since wood in these areas is gathered rather than bought. Militating against solutions is the fact that wood shortage is not considered a serious problem by all sections of the communities concerned. In urban centres, however, where fuel costs eat into a household's budget, conditions exist for the widespread distribution of improved stoves. People would be happy to accept more energy-efficient equipment that in no way requires them to alter their traditional behaviour. In theory, returns on investment are relatively rapid. But it has been noted that, with a few exceptions, distribution of improved stoves has not attained the expected results. This is due above all to the fact that actual yields are less than "in the laboratory". Studies have shown that in many cases they do not exceed 20%. These stoves are therefore not much more attractive than traditional ones.

Despite their technological simplicity, low cost, and appropriateness relative to traditional use, we must conclude that the introduction of improved stoves has been a failure. Twenty years after the first operations were launched, foreign technical assistance and bilateral and multilateral aid are still required. Many programmes have been funded by bilateral and multilateral aid institutions, and too often projects have terminated or stagnated when foreign aid was withdrawn.

Despite this fairly grim record, some success stories give cause for hope. In Kenya (one of the best examples), 500,000 improved stoves were distributed in a relatively short time. Disseminating an innovation is a slow process that demands a sustained effort, especially when the need for this innovation has not yet been urgently felt.

The improved stoves fulfil several complementary objectives:

- reduction of indoor pollution;
- reduction of time spent gathering wood;
- improvement of daily life;
- creation of jobs, and thereby increased income;
- securing of energy supply and environmental protection.

There is no ready-made strategy for distributing improved stoves. Each situation needs to be treated on its own merits by the local actors.

Other biomass in sub-humid and semi-arid zones

This category covers the various types of organic vegetable or animal matter and organic residues generated by human activity. The potential of these biomass sources in Africa's sub-humid and semi-arid zones is underexploited at the moment. To give one example, every year nearly 4000 Mt of biomass from African savannahs is burned. If its energy potential were put to effective use rather than wasted, this biomass would represent a significant contribution to these regions' development. One possibility would be to use the biomass to generate producer gas.

Profiting from the experience of Asian countries

Implementation of the Convention to Combat Desertification offers Africa an opportunity to rethink its energy development strategies. African countries must find ways to undertake the technical changes necessary to support a population that, unlike in other parts of the world, has not yet completed its demographic transition. From this point of view, the experience of Asian countries, particularly that of India (which is more populous than Africa), could be very instructive for African countries.

Back in the 1960s, everyone was making dark predictions concerning long famines in India and other parts of Asia. However, by tackling the problem head-on, India managed to triple its cereal production between 1950 and 1995. To achieve this, innovations were devised for mastering plant growth and developing irrigation and soil fertilization (thanks to massive and sometimes excessive, i.e. non-optimal, inputs). Oil-producing plants have also been developed to produce both conventional oils (e.g. palm, peanut or soy) and non-conventional ones (notably from non-food trees supplying soap-making in the semi-arid area of Rajasthan, as well as madhuca, pangamia, neem and pourghere, etc.). In addition, so that people no longer have to substitute dried manure for wood in areas where wood has become scarce, ways to economize on wood use have been developed. Types of chimneys have also been developed to carry smoke outside the home. Biogas use has been developed, albeit with varying results, and peasants have generally become capable of modernizing to increase productivity and better feed their countries.

Fertilizers have had a huge impact in China. A wide range of techniques, traditional, intermediary (like methanization) or modern, are used. In the suburbs of Shanghai, up to 600 kg of fertilizer is used per hectare per year (the European average is 200 kg, while in Sub-Saharan Africa it is just 12 kg), making it possible to produce 9 tonnes of cereal per hectare per year (3 tonnes of wheat, 6 tonnes of rice). Africa will certainly not attain similar production overnight, but we could draw inspiration from the medium technologies that Asia has adapted from the North at more competitive prices. And maybe further on down the line we, too, will be able to present some inspiring examples.

It may be in Africa's interests to develop hybrid technologies based on both Northern and Southern knowledge, in order to develop technologies for our African market that could not be developed in industrialized countries, which have no market for them. This could involve ways to better regulate water supply to plants, better fertilization, or maintaining the fertility of soil with nitrogen or phosphate inputs, producing more wood per area by irrigating and fertilizing even woody plantations, better product conservation, easier transformation of these products, etc. In each case, energy is required in one form or another. Capital is also necessary, so that farmers can show a surplus and invest in production-increasing methods that are not (or are less) dependent on the caprices of climate. In all cases, voluntary policies implemented, notably by India, to increase productivity (tax relief for use of fertilizers and electricity for water pumping), as well as the difficulties that may result from such policies, need to be studied (and not necessarily duplicated in all cases) to better determine the policies to follow. Furthermore, if we look at the possible evolution of per capita income over the next century, the majority of economic models indicate that India will have the most similar outcome to Africa's. Domestic energy consumption in rural areas will also continue to be dominated primarily by biomass. And in India, as in certain African countries, rice and the valorization of its sub-products will remain predominant.

It will be a long time before Africa becomes as populated as Asia. This is good news to some extent: forests will be replaced less quickly by cultivation. Agro-forests with intensive cultivation and animals kept in sheds will become necessary, but perhaps at a slower pace. Production will need to be intensified, but more gradually. Techniques such as production of biogas from animal waste will only become attractive when animals stop straying and are reared in sheds.

Africa has more biomass than India. As mentioned earlier, considerable quantities of energy go up in smoke every year with the burning of savannahs. Africa, which has the greatest extent of savannahs in the world, must take control of the valorization of these resources. The Danes have learned to valorize their corn mulch; the Asian countries are looking to valorize the sub-products of their rice sector; and other countries valorize wood. Attention should be focused on all these initiatives, so as to better valorize biomass resources.

Africa's low population density presents a handicap, especially for the huge extension of electrical networks, which is beyond the limits of national budgets. New energy policies, notably in drought areas, are necessary, particularly for the following reasons:

- lack of means required for installation of wide-

spread, linked energy networks;
- low consumption volume, and low income level, in the case of the majority of populations;
- the fact that needs to be met are very diverse, spread out and unevenly divided;
- absence or non-application of national energy planning, which should exploit to the maximum the different fossil fuels and renewable energy sources available.

Decentralized electricity production experiences in Asia, while not predominant, should not be overlooked. India's sugar industry has a large capacity for power co-generation. Today India exports sugar. Wind power could be very attractive to certain African countries. In addition, the manufacture of new high-performance biomass generators, such as dual-effect steam machines with combined heat (or cold in a few years, for sure) and power, should be carried out and adapted in Africa, drawing on the experiences of both Northern and Southern countries, and of Asia in particular. Photovoltaic solar power can be used for lighting and to satisfy low power requirements. To operate pumps, grain mills and even village welding, for example, much more powerful generators are needed, particularly those with 5-10 hp engines, which most African villages are already importing from India. These generators are petrol-based, but they could also operate on liquid, solid or gaseous biofuel if sufficient research were carried out.

It should be noted that while butane gas and kerosene are gradually replacing firewood for cooking in Asia and Latin America, small-scale industries are taking over this wood consumption. That Africa will follow the same path is not impossible.

The energy sector will remain essential to meeting future needs in agriculture, the social domain (water supply, food, health, education, etc.), economic development and the environment. Its role in combating desertification, while still not active enough, is nonetheless essential. So that rural populations can continue to manage their forests and obtain firewood from them, the pressure exerted on agricultural land (the main factor in deforestation) must radically diminish.

Conclusion

Taking the above into account, it is clear that cooperation between Africa and Asia, particularly with respect to energy technologies, offers huge opportunities for Africa to develop more rational energy policies. Up to now, that cooperation has not been adequately explored and/or sought after.

Technologies developed in Asia, though often modelled on those in industrialized countries, have more chance of being adopted by Africa due to certain characteristics shared by these regions. The story of the Thai bucket stove – which became the "JIKO" when adopted by Kenya and was then called "Diambar" upon its arrival in Senegal – is a fairly good illustration of this reality.

Aside from standard bilateral cooperation programmes, work and exchange links for valorizing bioresource energy technologies are currently being developed between the African and Asian networks. We can point out, in particular, the African Bioresources and Energy for Environmental Development Network (RABEDE) of West and Central Africa. Through contacts followed up in China and India, it has been able to identify diverse biomass conversion technologies representing a certain interest for the different network poles.

Collaborations between industrial partners and Asian research teams on one hand, and their African counterparts on the other, could be usefully developed starting immediately. These diverse initiatives deserve to be supported along with the standard cooperation programmes, reinforced in a very functional and concrete way thanks especially to political support in Asia and Africa. A more complete inventory of the initiatives should also be carried out. Multiform exchanges on energy technologies and bioresource conversion could then be developed.

From this base, transfer or joint finalizing programmes could be initiated, but this would mean establishing new financing mechanisms. The World Wide Fund for Nature (WWF) should help encourage and/or reinforce exploratory studies and transfers between Asia and Africa, with or without the cooperation of Northern partners. Other sources of finance, such as the Global Environment Facility (GEF), could undoubtedly be requested to strengthen the teams that have already displayed their skills, effectively using this type of cooperation in the interest of developing African countries. Why not further develop South-South-North cooperation in the interest of everybody, and of the environment in particular, instead of too often sticking to the North-South exchanges currently dominant? Development of these new forms of cooperation calls for high-level intervention.

Note

1. The CILSS is the Permanent Inter-State Committee for Drought Control in the Sahel (Comité Permanent Inter-Etats contra la Secheresse au Sahel). ◆

Shell International Renewables and sustainable rural electrification

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Shell International Renewables, launched in October 1997, is the Shell Group's fifth core business. Not that Shell are new to renewables: they have been active in forestry for over 18 years, and the first solar research by Shell started in the 1970s. Renewable sources are expected to provide 5-10% of the world's energy within 25 years, perhaps rising to 50% by 2050.

Setting up this new business marks a major step for the Shell Group, based on its commitment to sustainable development. So far, US$ 250 million has been spent on developing renewable resources, out of an investment budget of US$ 500 million. The initial focus is on four areas: solar power, biomass, wind energy and forestry.

Shell's activities relating to the use of renewable energy for rural electrification are described below.

Many rural communities worldwide do not have access to electricity. The World Bank estimates that two billion people are without basic amenities, including electricity. Many of these people currently use candles and kerosene for lighting, and wood for cooking, with negative impacts on the environment as well as on health and safety. Renewable energy could offer a solution. Rural communities' low power consumption, and the distance to the nearest electricity supply point, make extension of the national grid by local electricity companies unjustifiable from an economic point of view. Since there is no shortage of renewable energy sources, however, the development of renewable energy will have a significant role in bringing power to communities in rural areas.

The key question is: How can this be done in an economical, viable manner, given that affordability is low and that the local infrastructure for marketing, distributing, installing and maintaining renewable energy systems, and the required financial institutions, are lacking?

In 1987, Shell electrified the Indonesian village of Sukatani using *Solar Home Systems (SHS)*, consisting of a solar energy module, a battery for energy storage, and a charge controller. These systems, providing enough energy for lighting and television during a couple of hours per day, are still in operation, proving that technology is not an issue, although prices need to come down further for the market to grow. Shell has also electrified schools and clinics and provided solar energy (for sewing machines, weaving, irrigation, water pumping, etc.) that can be used in production.

In 1998, Shell made a serious start towards establishing a commercial business. A study was carried out concerning the countries to be developed first. GDP, political stability, government support, competition, the existing infrastructure and available financial support were considered, among other factors. Applicable marketing models were also examined. Since only limited experience was available on the right scale, it was decided to test a number of marketing models.

Fee for service in South Africa

In 1998, Shell and the South African electric utility ESKOM jointly developed a 50,000 SHS project in Quazula Natal, based on a monthly fee of US$ 10 and up-front payment of US$ 30. Economic analysis showed that a commercial project could be implemented on this scale. The project was to be executed in two phases. During the first phase, 6000 SHS would be marketed and installed; if a review found that customers were satisfied, and that technical features worked and financial arrangements were sound, the second phase (44,000 SHS) would follow. Special electronic equipment was developed by Conlog, a South African company based in Durban, and was housed in the dome of a triangular structure that later came to be called the "Power House System". This equipment included a pre-payment system and anti-tampering devices. To simplify installation and maintenance, system cabling was done with plugs and connectors (plug and play). Phase 1 was completed in May 2000, and a review was initiated. The results showed that customers were fully satisfied, although a few technical adjustments needed to be made to the Power House System and financial arrangements, particularly fee collection, required immediate attention.

During Phase 1, the Department of Minerals and Energy (DME) launched an initiative to establish concession areas. It invited companies to prepare business plans for the development of rural communities in these areas. The Joint Venture's plan was included. To date, discussions with DME on conditions, possible subsidies and the award of concessions

are still ongoing. This is the reason the Joint Venture has not begun Phase 2.

Cash and credit sales in India

India was chosen as one of the countries in which Shell would develop this business, addressing not only the rural market but also the potential market for grid back-up systems in case of black-outs. One of the main reasons for this choice was the *PV Market Transformation Programme (PVMTI)* initiated by the International Finance Corporation (IFC). A 100% Shell-owned renewable energy company, Shell Renewables India, was established at the end of 1998, since Shell was unable to choose a suitable company already active in this market.

The high import duties on SHS required Shell to produce modules locally and, where possible, to use locally manufactured components. An agreement was signed with Udhaya, an Indian company, to manufacture modules according to Shell's specifications. Shell provides all the material and pays Udhaya a fee for making the modules. The business plan was recently approved by PVMTI. Udhaya now manufactures 10, 25 and 36 Wp (watt peak) modules. Systems are successfully marketed and installed on a commercial basis.

Cash and credit sales in Sri Lanka

The potential market, and a World Bank subsidy of US$ 100 per system installed, provided reasons for Shell to enter Sri Lanka. Rather then establishing its own infrastructure, Shell decided to take over the Solar Power and Light (SP&L) company, which had marketing know-how, contacts, and distribution, installation and after-sales experience. In addition, an agreement was made with SEEDS, the credit lending organization, through which SHS could be marketed and SEEDS would provide credit to end-users. Since Shell took over SP&L, turnover has tripled. The US$ 100 subsidy will most likely come to an end in 2001, so a study has been undertaken on the application of a fee for service thereafter to further grow and develop the market.

The rural energy market in the Philippines

In 1995, Shell began by defining a 15,000 SHS programme in the Philippines, with financial support from the Dutch Government for the purpose of developing necessary infrastructure. The Philippines National Oil Company agreed to be the local partner. NGOs would be used to help with marketing, installation and follow-up after sales. Formal approval of this project is still pending.

Meanwhile, Shell defined another project in Alaminos using a photovoltaic-liquid petroleum gas (PV-LPG) hybrid unit to electrify an entire community of approximately 100 households through a mini-grid. Energy was to be sold on the basis of a weekly fee, making use of an energy switch (an electronic device that measures the amount of energy used and switches off when the user's limit has been reached). This was one of the models Shell wanted to test on the market. The Alaminos church was electrified at the end of December, followed by 80 households in March. A number of houses remote from the mini-grid were provided with a powerhouse unit, as applied in South Africa. The total system is called Sunstation.

Plans were further developed to replace the PV-LPG hybrid unit with a biomass unit using coconut shells, of which there is sufficient feedstock. Enough electricity would be generated for use in production. Shell's customers are very happy with this form of electricity (220 VAC), and it is planned to implement a number of "Sunstations" in the Philippines over the next few years. When enough experience has been gained, the model may well be applied in other developing countries.

Marketing renewable energy in Morocco

Morocco was chosen because of the PVMTI programme, as well as the country's existing Renewable Energy Policy and initiatives by the national utility company, ONE.

Rather then taking over a company, Shell decided to buy a major share in Noor Web, which has experience with battery charging and marketing, installation and after-sales services. The agreement was formally signed in August 2000. Noor Web won a tender for marketing, installation and maintenance over a period of two years for 7000 SHS in Taroudant. This company will participate in the tender for 20,000 SHS recently launched by ONE. The tender is based on fee for service.

Next steps

In the immediate future, Shell will evaluate various models and offerings and try the most effective and efficient ones. They will then be implemented in those countries offering the best opportunities. Further work will also be carried out on product offerings, particularly with regard to cost.

Capacity building: strengthening the Chinese renewable energy industry

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Summary
This article discusses examples of capacity building activities undertaken in China during the past 18 years. It focuses on knowledge transfer to national organizations, which can enable them to make better informed decisions. Through these organizations, technology and information sharing concerning renewable energy technologies can be expanded between China and other countries.

Résumé
L'article passe en revue quelques exemples d'activités de renforcement des capacités menées en Chine depuis 18 ans. Il s'intéresse principalement au transfert de connaissances vers les organismes nationaux comme moyen permettant de prendre des décisions éclairées. Ces organismes contribuent à développer, entre la Chine et d'autres pays, l'échange de techniques et d'informations sur la technologie des énergies renouvelables.

Resumen
Este artículo examina ejemplos de actividades orientadas a ampliar la capacidad, que se han emprendido en China en los últimos 18 años. En particular, analiza la transferencia de conocimientos a las organizaciones nacionales, lo que les permite tomar decisiones mejor fundamentadas. A través de dichas organizaciones, China puede compartir más ampliamente la información y la tecnología acerca de las energías renovables con otros países del mundo.

Around 1.3 billion people in developing countries have gained access to an electricity supply in the past 25 years. However, the global population has increased by 2 billion over same period, resulting in 700 million more people being without electricity. The total number of people without electricity now stands at approximately 2 billion, and this number is increasing. The electricity grid will never reach the vast majority of these people, as it would be too expensive. This means that, in most cases, renewable energy technologies are the only sustainable solution.

In order for these solutions to be implemented, the capacity of local institutions needs to be developed. This article looks at the lessons that can be learned from the work on capacity building and technology transfer in China undertaken by IT Power for a wide range of institutional clients over the last 18 years.

Renewable energy capacity building in China

The pace of renewable energy development in China is rapidly increasing.[1] More and more developers are in the process of entering the Chinese market, increasing the number and scale of new renewable energy projects within the country to exploit what has long been know to be a huge resource.

In the case of photovoltaics (PV), for example, the total installed capacity of PV systems in China at the end of 1999 was only approximately 13 MW[2], distributed among applications in the telecommunications, industrial, agricultural, consumer and rural electrification fields (projections for solar PV installed capacity are widely considered to be a lower limit). However, several large-scale projects under development will rapidly expand the PV market in China. One example is a 10 MW solar home system programme being developed by the World Bank for western China.[3] Another involves the Shell Company, which is implementing a large-scale solar home system project in the Province of Xinjiang.[4] In addition, several large-scale solar home system and village power projects are in the approval stage in the Brightness Programme, under the Chinese State Development Planning Commission.[5] Similar examples of this increased scale of development can be found in the markets for large-scale wind farm developments, solar water heating applications, biogas plants and bagasse co-generation.

Table 1
Potential for selected renewable energy technologies in China[6]

Technology	1998*	2010*
Solar PV (MW)**	13	56
Solar water heaters (10^6 m^2)	15	171
Grid-connected wind (MW)	224	3000
Small wind (MW)	17	430
Geothermal power (MW)	25	100
Biogas livestock farms (10^8 m^3)	0.6	2.8
Biogas industrial wastewater (10^8 m^3)	3.2	24

* Cumulative
** Projections for solar PV installed capacity are widely considered to be a lower limit

The increasing scale of renewable energy development within the country has major implications for business development and finance organizations within China and internationally. Mechanisms are now needed to support local organizations' commercialization of the sale of renewable energy technologies, so as to facilitate the next stage of market expansion. Most of the domestic renewable energy business base in China has limited experience in project development with commercial financing of large-scale projects, and with international standards. Capacity building and technology transfer is needed to bridge these gaps and to promote the dissemination of state-of-the-art commercial technologies, achieve cost reductions, and improve the manufacturing base in China. Information exchange is needed to promote international best practices for project development and financing, facilitate business interactions between domestic and international organizations, and provide an interface between domestic industry groups and key government decision-makers and other stakeholders.

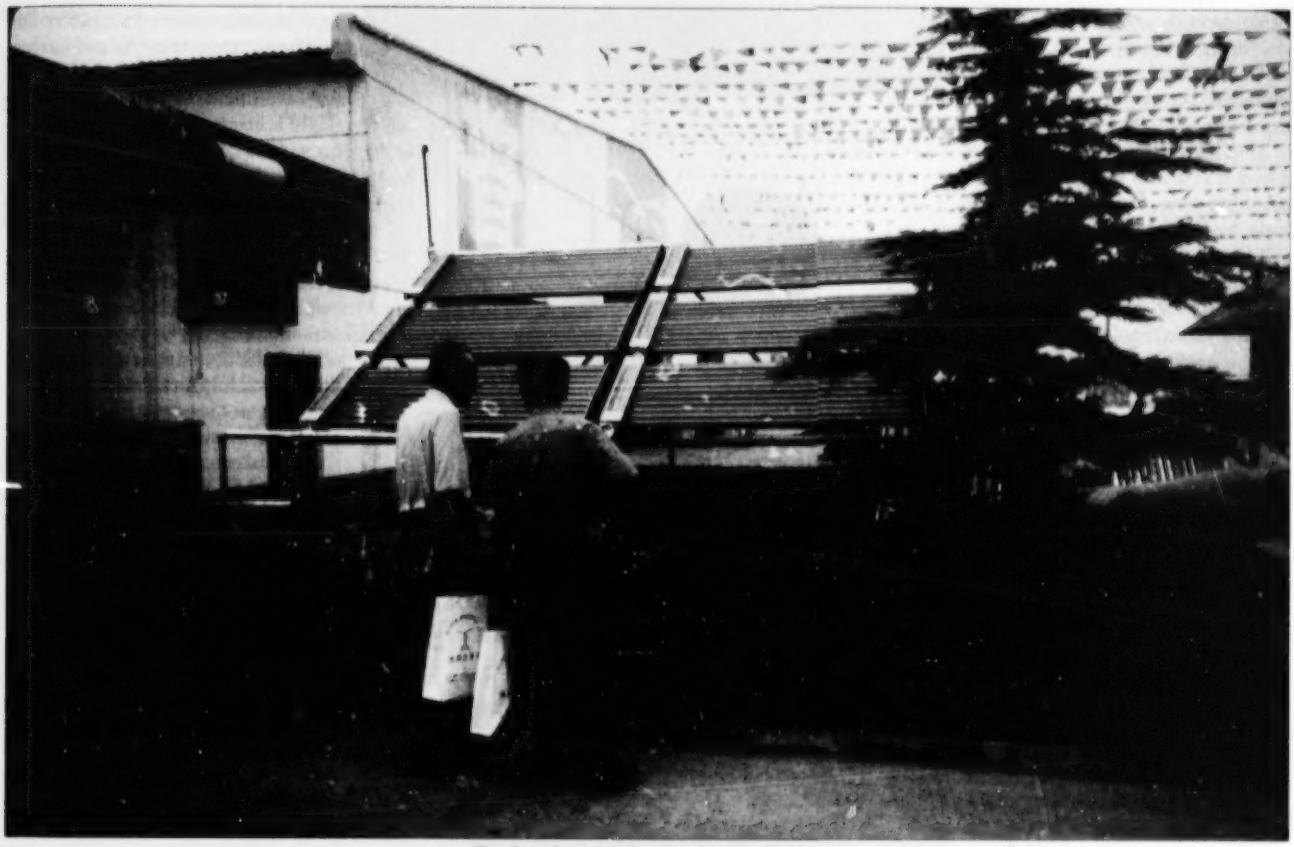
The potential for renewable energy in China

An indication of the potential for selected renewable technologies is given in **Table 1**. The potential for accelerated commercial development is especially significant for grid-connected wind and solar water heating technologies.

While these new renewable energy technologies are set to see a large increase in deployment, the Chinese market for small-scale hydropower (SHP) equipment is already mature. There are more than 45,000 SHP schemes in operation in China, having an installed capacity of over 19,000 MW, and new capacity is being installed at a rate of approximately 1000 MW per year, making it by far the largest in the world. In addition, it is estimated that between 6000 MW and 8000 MW of capacity needs to be upgraded at existing SHP sites.

Government policies

Policy initiatives for renewables formulated by central government agencies in China are a major part of the Government's planning processes for the 10th Five-Year Plan (2001-05). Provincial governments are also developing policy initiatives and the Chinese State Development Planning Com-



TianPu solar water heating factory, Beijing

mission, with foreign expert assistance, is presently assessing the potential for Renewable Energy Portfolio Standards (RPS), and other policy mechanisms, to promote renewables across the country. Solar and wind systems are now being integrated into the rural electrification expansion plans of most western provinces as an important option for village electrification.

Industry status

Table 2 provides estimates of the number of companies operating in selected renewable energy market sectors. Most market sectors are subject to heavy competition among a large number of small companies. Product quality is often poor, and profit margins are low. In many market sectors consolidation is occurring, with larger successful companies beginning to increase market share and smaller companies merging or going out of business.

Barriers to commercialization

Despite over 18 years of field deployment and international funding, there are still many barriers to the commercialization of new renewable energy technologies in developing countries such as China. They range from underdeveloped infrastructure (product distribution networks, financing organizations, technician training, etc.) to uncoordinated national and local energy priorities. These problems are not specific to China, but can also be found in many developed countries as well. More specifically, market barriers include the following:

- poor development and application of product manufacturing and installation standards, certification and testing, required to insure quality and safety;
- very few financial institutions familiar with the characteristics of renewable energy project financing, or willing to finance either business development or individual product purchases;
- generally poor linkages from research and development to commercialization, due to lack of development capital and cutbacks in government support of R&D;
- restricted accessibility to renewable energy resource databases;
- weak coordination between agencies responsible for renewable energy planning, reflected in the lack of a long-term strategic plan for sustainable renewable energy commercialization;
- lack of a systematic and comprehensive policy structure to support renewable energy development across sectors (e.g. agriculture, healthcare, micro-enterprise development);
- general lack of public and stakeholder awareness of the benefits and availability of renewable options;
- the high cost of domestic renewable energy technology in some market sectors;
- few intermediate organizations able to provide services to renewable enterprises in order to assist with market development.

Table 2
Industry groups in terms of estimated number of manufacturing and distribution companies

Market sector	Large companies*	Small companies
PV	5	>45
Wind		19
Solar water heating	10	1000
Biomass	20	600
Geothermal		30

* Companies of sufficient size to take advantage of economies of scale in manufacturing or distribution

Source: Chinese State Economic and Trade Commission

Building capacity within renewable energy organizations in China

The development of the Chinese Renewable Energy Industries Association (CREIA), and the strengthening of the International Network on Small Hydro Power in Hangzhou (IN-SHP), have been important aspects of IT Power's capacity building work in China.

The Chinese Renewable Energy Industries Association

In March 1999, the UN Development Programme (UNDP) initiated a project on Capacity Building for the Rapid Commercialization of Renewable Energy in China. Its main objective has been to support acceleration of the commercialization of renewables by addressing policy, business, finance and technical issues through capacity building activities. Corollary objectives include achieving a detectable increase in technology

deployment through project activities, developing a strong interface with industry and investment communities, and promoting the transfer of international experience and technology to China.

The GEF/UNDP Project is funded at a level of US$ 25.8 million over a period of five years. Core funding comes from the Global Environment Facility (GEF) and the Chinese Government, while co-financing contributions come from Australia's AusAID Programme and the Government of the Netherlands. The project is implemented by the Chinese State Economic and Trade Commission (SETC) in Beijing and executed by the UN Department of Economic and Social Affairs in New York.

One of the major activities in the GEF/UNDP project is supporting the establishment of the Chinese Renewable Energy Industries Association. Both UNDP and the SETC are providing initial support for CREIA staff and facilities during a three-year period. The aim is that after five years the organization will become fully self-supporting through membership fees and services, resulting in long-term legacy of the GEF/UNDP project.

In 1999, a contract to support CREIA was awarded by UNDP to a team consisting of IT Power in the UK and Alternative Energy Development, Inc. (AED) in the US. The support team is working with members of the CREIA staff to prepare a five-year business plan and marketing strategy for the organization that will allow CREIA to become fully self-supporting in five years.

In January 2000, CREIA was formally registered as CREIA Renewable Energy Ltd. under Chinese corporate law. Corporation status is temporary, pending approval of CREIA's application to the Chinese Government for trade association status. A Board of Directors and Secretariat have been appointed, as well as the first Director of CREIA, Mr Zhu Junsheng.

CREIA has been set up as a non-profit corporation. Although it receives initial support from the State Economic and Trade Commission in China, it is not formally associated with a government organization. This non-governmental status distinguishes CREIA from most existing trade associations in China, which are frequently departments of a government agency. As such, trade associations in China in the past have been more responsible to the Government than to their industry membership base.

CREIA will play an advocacy role on behalf of industry, so as to raise the general profile of renewable energy technologies and applications and industry as a whole. This includes information dissemination to the public and public education. It will provide a communication network for its members from the Chinese renewable energy business community, in order to allow members to communicate across their respective sub-sectors and provide a platform to voice their concerns collectively.

Solar cooker demonstration

The organization is conducting a membership drive to attract a wide base of support from renewable energy companies. High priority market sectors for membership in the organization include companies working in the fields of solar photovoltaics, solar hot water heaters, biomass, grid-connected wind farms, small wind technologies, geothermal power, and hybrid systems.

Other trade associations can also attain member status. Provision has been made for foreign companies to join CREIA as international affiliate members, allowing them to register in CREIA's company database and giving them access to information services. In the initial phase of CRIEA development, Chinese companies will be given full membership status.

The main objective of CREIA is to work with Chinese renewable energy industry groups to promote sustainable renewable energy development based on market-oriented commercialization principles. It will serve as a bridge between regulatory authorities, research institutes and industry professionals, providing a forum to discuss renewable energy development at the national level. Subsequently, CREIA will play an advocacy role on behalf of industry to advise the Government on strategic policy formulation.

One of the other main aims of CREIA is to raise awareness of renewable energy investment opportunities within the country and help bring together national and international project developers and investors. An Investment Opportunity Facility (IOF) is being developed, and regional networking meetings and training activities will be conduits for information exchange. Specifically, the IOF will work in close partnership with CREIA members to provide guidance, supporting information and technical assistance to help members obtain investment partners and financing for the development of renewable energy projects. In addition, the IOF will help members recognize and capitalize on the growing opportunities for renewable energy investments to mitigate global climate change. In combination with the IOF information databases, CREIA will conduct investment opportunity forums to create opportunities for project developers, entrepreneurs, and companies to meet directly with investors and financial institutions interested in renewable energy projects. Active outreach to the financial community has already started.

In the latter half of 1999, a series of consultative activities were conducted with companies, industry groups, government organizations and investors in China. These consultations provided feedback from industry regarding their expectations and needs, and also resulted in recommendations for structuring the CREIA organization. A formal institutional workshop for the organization was conducted in January 2000. The workshop was attended by over 30 key companies and trade associations in China, which have become founding members of CREIA. The companies are major representatives of the wind, PV, solar water heater, biomass and geothermal business sectors.

In April and May of this year, consultations with businesses, investors and trade associations were conducted by CREIA staff and corporate members in the US and Europe. These consultations included information exchanges between CREIA and experienced trade groups, which was used to further develop a proposed inventory of information and services that CREIA will provide to its membership. Business contacts were also made between foreign and Chinese companies, and with foreign investors and financial institutions.

A series of business and management training activities aimed at developing renewable energy project identification skills, project assessment and preparation capabilities, and awareness of domestic commercial and international sources of financing for renewable projects within CREIA have been carried out. Further training will target CREIA board members, operational staff, renewable energy project developers, financiers, and government decision-makers.

CREIA's membership and public services will include making available a series of databases on the CREIA website. Databases linked with the

IOF will include a membership information base with company profiles and contact details, profiles of financial institutions and financing intermediaries, and information for presenting and tracking projects and proposals. CREIA will also make information available on China's renewable energy resources, financing channels and methods, and renewable energy technologies within China.

CREIA will collaborate with the GEF/UNDP project in conducting policy, business, finance and technical workshops and training events to promote renewable energy commercialization objectives. For example, CREIA will be involved in standards and certification activities, finance training for project developers, and regional workshops for technology and application information dissemination.

During 2000, CREIA will conduct a solar thermal standards and certification workshop and PV workshop (in October in Kunming, China). CREIA will be a major sponsor and organizer of the China International Environment, Renewable Energy, and Energy Efficiency Exhibition and Conference, to be held in Beijing between 28 November and 1 December. At this event CREIA will conduct two workshops directed at project financing for large-scale wind farms and renewable energy opportunities in China's western development initiative.

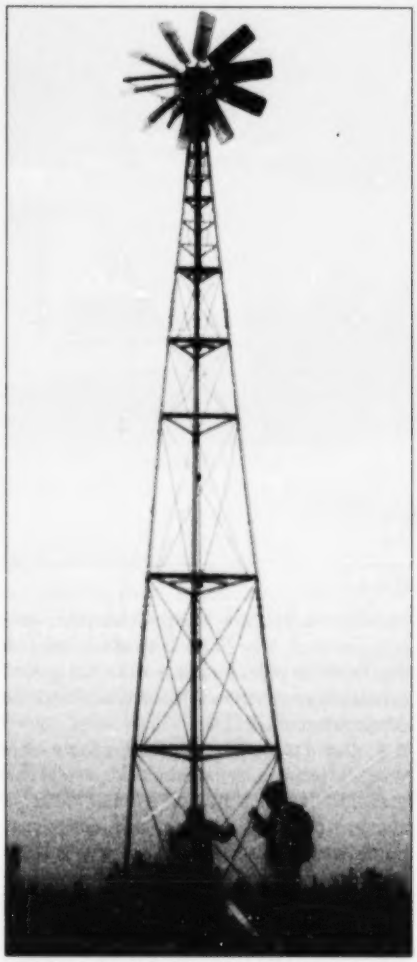
The International Network on Small Hydro Power in Hangzhou (IN-SHP)

Since 1993, IT Power has been working with IN-SHP to develop its capabilities in regard to developing an international network on small hydropower. This has involved various activities financed by the UN Industrial Development Organization (UNIDO), including several international seminars between 1993 and 1996.

In 1997, IT Power was awarded a contract by the European Commission Joule-Thermie programme to Promote EU-China Collaboration in Small Hydropower. This was supported by UK DFID and by the Ministry of Water Resources, the Ministry of Foreign Trade and Economic Co-operation, and the Ministry of Science and Technology in China. The programme included:

- exchange of information on small hydropower in Europe and China through the publication of a Technology Guide for each region;
- conducting a forum for exchanging experiences in SHP development through a joint EU-China workshop held in Hangzhou in April 1999;
- making recommendations for a joint strategy to accelerate uptake of SHP systems worldwide;
- enhancing the level of practical co-operation between the SHP industries in Europe and China, so as to promote better quality and lower costs in responding to the market needs of small hydro projects.

Significantly, the project established a permanent networking relationship between key Chinese and European SHP organizations and raised the international profile of the International Network on Small Hydropower, enabling it to promote the concept of SHP worldwide more effectively.



IT Power-developed, but locally manufactured, small wind pump installed on an agricultural holding in Cagxian County

Lessons for future capacity building initiatives

There are many aspects to transferring technology and building capacity in developing countries. It is certainly not enough to set up a manufacturing base and expect the transfer to be a success. An essential part of technology transfer is the development of management skills and ongoing information exchange. Training overheads need to include investing in the learning curve in regard to management and engineering, and the implementation of quality control for both.

Of particular importance is the need for continuous communication between the project partners, to make sure everyone involved is committed to the process and receives the information required at all stages.

Questions such as the following need to be asked, so as to make sure the project is as relevant and sustainable as possible. This list is by no means exhaustive, but provides a starting point from which to analyze each local situation:

- What are local needs?
- What are the available resources (technical, professional, natural)?
- What can be transferred to assist in fulfilling the need?
- What is the best method of transfer?
- How can the project be designed so that it is replicable?
- Who are the most appropriate recipients of this knowledge?
- How can the recipients be assisted in helping to disseminate the know-how?

Technology transfer projects, as distinct from capacity building at a local level, have additional criteria by which to judge their relevance and likely chances of success. Issues to be addressed include:

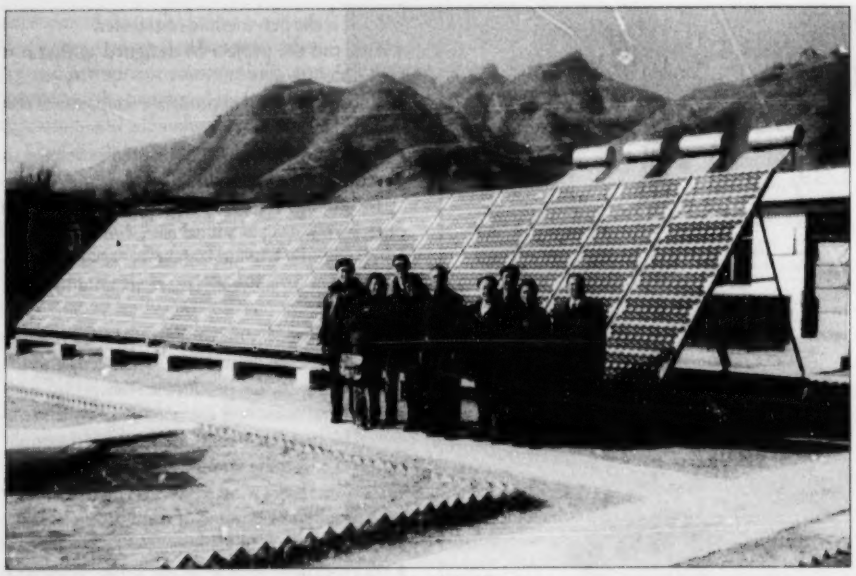
- Is there a need for the product? (Market research may be undertaken to assess local needs and the ability to pay for the product/service.)
- If natural resources are used (e.g. wind, sun, water, biomass), are they adequate for the application (i.e. is there enough sun annually to provide power? Is the wind regime too high or too low for a certain power rating of wind turbines? Is the wood resource sustainable?).
- Priorities need to be set at the outset (geographical, applications, recipients, technologies, etc.).
- The project needs to be economical, replicable and sustainable.
- Demonstration of the technology has to be undertaken before the project begins, in order to demonstrate to the potential customers that it does work.
- In order for people to afford to purchase the technology or service, appropriate local financing has to be available for small purchasers.
- Installation, replacement of equipment, and maintenance require training and infrastructure development need to be arranged at the local level.
- For a technology transfer project to be successful in the long term, there has to be adequate funding and the allocation of risk needs to be distributed across the project participants.

Conclusions

Once it was considered enough to transfer technology without considering the wider ramifications of developing new applications for renewable energy technologies in developing countries. History has shown that such projects generally fail. However, where the market, all the players, and the project's long-term sustainability have been considered from day one, and investments have been made in human resources (training of managerial and policy staff, as well as technical personnel), there have been considerably greater levels of success. In the case of renewable energy developments in China, it has been realized for some years now that such investments are necessary in order to realize a project's technical goals. IT Power is proud to have been part of this process.

Acknowledgements

The author would like to acknowledge: financial support from the GEF/UNDP Project CPR/97/G31; IT Power's partners in the development of CREIA (AED and CRED) and the staff of CREIA; financial support from UNIDO for small hydro work in China; and the collaboration of the staff at IN-SHP.



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Visit the CREIA *website on* www.creia.net *or* www.itpower.co.uk/creia, *and IN-SHP on* www.digiserve.com/inshp.

IT Power is an international energy consultancy with 20 years' experience working on renewable energy projects in developing countries. The company has completed more than 600 contracts in over 90 countries worldwide for most of the UN agencies, EC Directorates, and numerous government agencies and private clients. Most of these projects have included some form of capacity building. ◆

Energy efficiency for green business

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Summary

India is a developing country with a high rate of industrialization. A broad spectrum of possibilities therefore exist for improving efficiency and saving energy. India's cement industry, which has attained world standards for energy efficiency during the past decade, provides examples of approaches to solving the twin problems of sustainable development and environmental protection.

Résumé

Parce que l'Inde est un pays en développement qui s'industrialise à un rythme accéléré, les possibilités d'améliorer le rendement énergétique et d'économiser l'énergie y sont innombrables. L'industrie indienne des ciments, qui a atteint un rendement énergétique comparable à la norme mondiale au cours de la dernière décennie, offre divers exemples d'approches du double problème du développement durable et de la protection de l'environnement.

Resumen

India es un país en desarrollo que posee un alto índice de industrialización. De modo que cuenta con múltiples posibilidades de hacer un uso más eficaz de la energía, con miras a ahorrarla. La industria del cemento, que en la última década alcanzó los baremos mundiales de ahorro energético, proporciona ejemplos de cómo solucionar los problemas íntimamente vinculados del desarrollo sostenible y la protección medioambiental.

Energy is an essential factor in economic activity. It contributes directly to meeting both basic and more sophisticated human needs. Regardless of the form it takes – primary (coal, natural gas, oil, etc.) or secondary (electricity) – energy is essential to a country's economic growth and sustainable development.

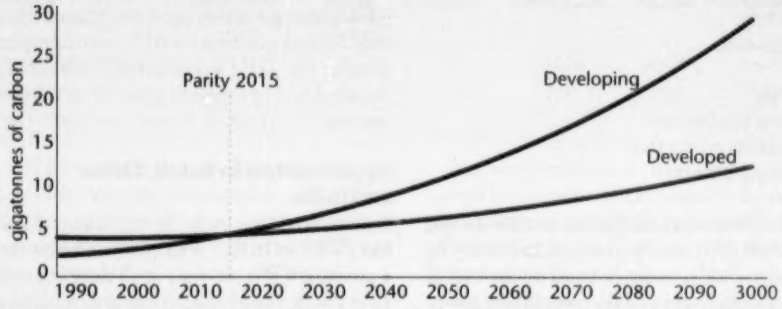
Energy is necessary as a means of production, and for its contribution to the quality of life. Since the industrial era began, fossil energy has supported economic growth, leading to a sharp increase in greenhouse gas emissions and their build-up in the atmosphere. Fossil fuels represent 84% and 92% of commercial energy use in developed countries and the rest of the world, respectively. Some of the most challenging environmental problems are directly linked to energy production, transport, storage and use.

Energy efficiency has improved considerably since the 1970s, in response to energy price

increases, supply uncertainties, government policies and independent technological improvements. Further improvement is still possible in all economies. Some studies indicate that energy savings of 20-30% could be obtained cost-effectively over two to three decades through improving energy-using technologies and the energy supply system. Resource depletion, the increasingly evident impacts of climate change, and rising demand for energy-intensive activities are additional reasons to develop an energy-efficient global economy.

With concern about global warming growing the world over, countries (especially developing ones) need to adopt technologies that not only address the problem of sustainable development but also the grave problem of climate change.

Figure 1
Annual industrial emissions in industrialized and developing countries



Source: Duncan Austin, J. Goldemberg and G. Parker, Contributions to Climate Change: Are Conventional Metrics Misleading the Debate?

Trends in energy intensity

Shifts to commercial energy sources during the course of economic development lead to decreases in energy intensity, as does the introduction of more efficient energy production processes. The general dynamics of energy intensity are influenced by three overlapping phases:

- shifting from non-commercial to commercial energy;
- more efficient commercial energy use;
- in many cases, substitution of electricity for direct use of fossil fuel.

Factors such as geography and climate, population density, resource endowment and economic structure also influence energy use across countries.

The Industrial Revolution began way back in the 18th century. The industrialized countries passed through a period in which energy intensities grew at an increasing rate, with accompanying carbon emissions. However, the scenario has changed since. Energy intensities have actually shown a downward trend. On the other hand, they will probably increase in developing countries that have just embarked on the path of growth. These countries are likely to be the major emitters in the coming years, achieving parity with the industrialized countries (in terms of annual emissions or of stock emissions) in the foreseeable future (**Figure 1**).

Delinking GHG emissions from growth

Population increases and economic growth are both associated with greater energy demand. Since energy supply in most countries is largely based on fossil fuels, carbon emissions tend to increase rapidly with development, particularly in countries with relatively low per capita incomes. Among developing economies (excluding China), GDP grew 2.8% per year between 1980 and 1994 while commercial energy consumption grew 4.7% (**Table 1**).

The energy demands of industrialized economies are far higher than those of agricultural ones. As per capita income increases, household energy use grows. In high-income countries, growth in energy consumption becomes increasingly "decoupled" from GDP growth for a number of reasons. These economies often experience shifts from energy-intensive industrial sectors to less intensive service sectors. Moreover, in certain sectors such as households most consumers reach income levels at which further growth in consumption of energy-intensive appliances slows. Finally, technological advances increase energy efficiency, holding down energy demand even where economic activity is growing. As a result of these factors, carbon emissions in some OECD countries have been stable or declined in recent years.

Data collected over more than a century on some of the industrialized countries (e.g. Germany, France, Japan, the UK and the US) permit assessment of long-term energy intensity trends. It is well known that these countries' energy intensity increased as infrastructure and heavy industry developed, then peaked and began a steady decline. Latecomers to the industrialization process, such as Japan, peaked at lower energy intensities than their predecessors, indicating early adoption of innovative and modern, more energy-efficient industrial processes and technologies ("technological leapfrogging").

Table 1
Average annual growth of GDP and energy consumption (1980-94)

Economies	Annual growth of GDP (%)	Annual growth of energy consumption (%)
Low income	2.8	4.7
Upper middle income	2.5	3.9
High income	2.8	1.1

Source: Promoting Development while Limiting GHG Emissions: Trends and Baselines (WRI paper)

Why growing emissions are a cause for concern: the options available

The Earth's natural greenhouse effect, which traps some of the sun's energy and makes our planet habitable, is being thrown out of balance by increasing amounts of heat-trapping air pollutants. Carbon dioxide, the leading global warming gas, is released in large quantities mainly when coal, oil or gas are burned. CO_2 emissions increased 12-fold during the 20th century. There is now 30% more CO_2 in the atmosphere than when extensive burning of coal began during the Industrial Revolution.

The first impacts of global warming are being felt on every continent and in most countries, in the form of floods, droughts, melting of glaciers and the spread of infectious disease. There is worse to come, unless responsible steps are taken to reverse the rising trend of CO_2 output. The UN Framework Convention on Climate Change (UNFCCC) was signed in 1992. At the third Conference of the Parties in 1997, the Kyoto Protocol was signed. If ratified, it will bind developed countries to achieve the agreed level of emission reductions by 2008-12. Since developing countries are expected to contribute significantly to emissions, mitigation strategies could help at a negative cost without affecting economic growth. In other words, such strategies would result in reducing energy intensities without affecting the respective country's aspirations for sustainable development.

Mitigation options in the following areas could be introduced in various countries:

Energy

- improved end-use efficiency in households, industry, services;
- transmission systems;
- fuel substitution;
- renewable technologies (decentralized);
- supply technologies (centralized): fossil fuels, nuclear and renewable.

Agriculture

- fertilizer control schemes;
- introduction of crops with greater carbon sequestration capability;
- livestock management: manure treatment, feeding;
- cultivation of rice paddies.

Forestry

- afforestation projects;
- increasing forests' carbon sequestration capability (increasing biomass density);
- recycling or permanent storage of carbon sequestered in harvested biomass;
- reforestation.

Transportation

- improved vehicle efficiency;
- fuel systems with lower emissions;
- better transport system efficiency;
- modal shifts;
- management of transport demand.

Waste management
- gas recovery from landfills;
- biogas plants;
- recycling;
- composting.

Industry
- cement production;
- aluminum production;
- the paper industry.

The technologies used to achieve the desired results will differ among countries. In developing countries, choices would be based on the level of existing technologies and the cost-effectiveness of the technologies being considered.

Benefiting from the Clean Development Mechanism

While a number of mitigation options are available, developing countries face several barriers to implementation. These may include subsidies, high tariff barriers and other such impediments, and lack of information on new technologies. Developing countries also tend to be capital-starved, making the adaptation of high-end technologies difficult. They could take advantage of the "flexibility mechanisms" in the Kyoto Protocol, such as the Clean Development Mechanism (CDM), designed to help make technologies and financial help from industrialized countries available.

The Kyoto mechanisms are intended to reduce overall compliance costs by allowing parties to share emissions reduction commitments through joint implementation and offset trading. The purpose of the CDM, whose main objectives and provisions are included in Article 12 of the Protocol, is to assist developing countries in achieving sustainable development, while helping them reduce GHG emissions and achieve compliance. However, a major question raised by many people is whether the CDM would actually advance the sustainable development goals of developing countries.

Opportunities in Brazil, China and India

Studies carried out by the World Resources Institute (WRI) in India, China and Brazil show that:
- potential CDM projects in all three countries offer a wide range of sustainable development benefits, including environmental benefits such as cleaner air and water, reduced deforestation and soil conservation, and many social benefits such as rural development and employment generation;
- in many cases, these benefits overlap markedly with goals that developing countries identify as development priorities. Far from skewing investment priorities in developing countries, CDM offers an opportunity to make progress simultaneously on climate, development and local environmental issues;
- explicit assessment of a project's non-carbon or sustainable development attributes is important if developing countries are to design and prioritize projects such that these projects are as consistent as possible with the countries' own development goals.

These findings suggest that the CDM would indeed be able to provide substantial development benefits, as required.

In Brazil, both the forestry and energy sectors present opportunities for CDM projects. In view of its forest resources, and present emission trends associated with deforestation, forestry initiatives have vast potential. In the electricity sector, supply is dominated by hydroelectricity although a business-as-usual approach indicates a greater role for fossil fuels, particularly natural gas and fuel oil. Various forms of energy co-generation and renewable energy use could limit this expansion.

The handling of China's coal reserves, on which the country is largely dependent for its present energy needs, will be central to its economic development over the next few decades. A great many projects that could be undertaken in China are consistent with both global and local development concerns.

This article concentrates largely on India, as it is not only a developing country but also has a high industrialization rate and so offers a wide spectrum of possibilities for improving efficiency and energy saving. One can assume that what is applicable to India will to a certain degree also hold true for all other developing countries. In addition, what is applicable to energy consumption in the industrial sector will be applicable, in some respects, to other raw materials and natural resources.

When we look at structural changes in industry, India differs markedly from countries like Austria, Belgium, Denmark, France or Germany. The growth in factors with negative environmental effects in India occurred faster than GNP growth, a trend contrary to that in the industrialized countries. Energy production's higher growth rate suggests structural changes, with a build-up of energy-intensive sectors. This process could easily continue, as per capita energy consumption is still low. If it continued unabated, it would lead to an increase in temperatures, which could lead to the displacement of millions of people due to land loss. Some crop simulation studies also estimate a drastic reduction in wheat yields, which could be extremely damaging to the Indian economy. Thus, there is a growing need to address the issue by adopting energy-efficient technologies. This would not only reduce emissions, but also make business sense for the country.

India has great potential to reduce its greenhouse gas emissions. Investment projects can produce substantial reductions in GHG emissions, particularly those of carbon. India's high generation capacity, which is largely coal-based, produces high emissions. It offers an excellent opportunity to improve generator efficiencies and emissions management. Coal washing to reduce ash content represents US$ 1.8 billion in potential investment, while switching from coal to natural gas (imported LNG) in coastal areas represents an additional US$ 3.1 billion investment. In the longer run, although coal is forecast to dominate, India could support significant amounts of renewable technology capacity – wind, solar and biomass.

Table 2 summarizes the results of a study of ten energy-intensive sectors. It estimated that an investment of US$ 1 billion could eliminate the 20% discrepancy between Indian facilities and international best practice in the area of energy use, while allowing export industries to become

Table 2
Energy-intensive industrial sectors in India

Project category	Emissions mitigation opportunity	Size of opportunity	Overall investment potential	Energy benefits expected	Carbon reductions expected
Electricity generation					
Coal washing	Reduction of ash content from 40 to 30%	5000-6000 MW of capacity	$1.8 billion	5500 Btu/kg coal	11 million metric tonnes/year
Fuel switching	LNG importing in current coastal coal plants	3800 MW	$3.1 billion	0.15 kg carbon/ kWh	4 million metric tonnes/year
Conventional efficiency	1.5% improvement of thermal efficiency	6500 MW	$0.15 billion	Not available	4 million metric tonnes/year
IGCC power	Installation of IGCC technologies	10,000 MW	$10 billion	2000 Btu/kWh	5 million metric tonnes/year
Renewables	Wind, solar, bagasse and mini hydro	35,000 MW	$25 billion	0.35 kg carbon/kWh	60 million metric tonnes/year
Industrial sector					
Caustic soda	Conversion of mercury cell process to membrane cell	900,000 metric tonnes of capacity	$8.4 billion	500 kWh/ metric tonne produced	120,000 metric tonnes/year
Cement	Upgrading from wet to dry process	45,000,000 tonnes of capacity	$4 billion	90 kWh/metric tonne produced	1.1 million metric tonnes/year
Aluminium	Upgrading to Hall-Herault process	Balco and Indal plants	$8.4 billion	1500 kWh/ metric tonne produced	Not available
Steel	Updating of open hearth process plants	Not available	$4.3 billion	2.8 Mmbtu/ tonne of clinker	0.8 million metric tonnes/year

Source: Haigler Bailly, Climate Change Handbook

more cost-effective in global markets. In the industrial sector, iron and steel, textile and aluminimum account for nearly 70% of the efficiency potential.

In the near term, most climate change investments are likely to be made in the industrial and power sectors. These investments will not only reduce emissions, but also lower energy intensity, thus attaining global efficiency levels in these sectors.

The Indian cement industry at a glance

When we speak of industrial sectors, India's cement industry comes to mind. Cement, one of the core industries, is next to iron and steel in terms of the country's overall energy consumption. Cement is one of those sectors that exhibited remarkable advances during the 1980s in India. The switchover from low-capacity, energy-inefficient wet plants to high-capacity, energy-efficient dry process has effected the lowering of specific energy intensities from 900 kcal/kg thermal energy to 800 kcal/kg and 120kWh/tonne electrical energy to 90kWh/tonne. Today plants are on the drawing board with specific thermal energy consumption at 715 kcal/kg of clinker, while specific electrical energy consumption stands at 75 units/tonne of cement.

A joint study by the US Agency for International Development (USAID) and the Cement Manufacturers' Association (CMA) carried out a comparative survey of typical Indian cement plants and those in Japan, South Korea, Taiwan and Thailand with respect to energy conservation and management practices. When data on energy consumption levels in state-of-the-art cement plants in India and the other countries were compared, India had the lowest power consumption (kW/tonne cement) and was second only to Japan in fuel consumption (kcal/kg of clinker). The Indian national average, which includes old plants, shows that efficiencies must nevertheless improve further (**Table 3**).

The above presentations indicate the extent of savings possible in an industry solely through energy-efficiency measures. Improvements in fuel consumption rates would make the industry cost competitive and reduce GHG emissions, thus making it a win-win green business strategy. Further process improvements and a sectoral shift, i.e. from energy-intensive production to services, would have a bearing on the fuel mix and hence the country's energy consumption levels. What becomes apparent is that energy efficiency improvements are of great importance, although other improvements will be needed as well.

Table 3
Comparison of energy consumption levels

Energy	India: three modern plants	Indian national average	Japan	South Korea	Taiwan	Thailand
Power (kWh/tonne cement)	80-85	115	97.8	99-100	98-100	103-105
Fuel (kcal/kg clinker)	690	815	653	710	730	720

Source: Bulletin on Energy Efficiency, Vol. 1, August 2000

Table 4 presents three cases of technology improvements implemented successfully at Indian cement plants. These cases show how energy efficiency can be reached in an environment-friendly way, with reduced energy consumption leading to lower GHG emissions. Implementation of these projects resulted in annual savings in the order of Rs. 0.17-37.0 million, depending on the technological changes implemented. The annual savings were a result of increased production and thermal energy savings.

Financing energy efficiency

According to a WRI study, by the late 1990s bilateral banks consisting largely of Export Credit and Investment Insurance Agencies (ECAs) accounted for 31% of all long-term financing received by developing countries. Rather than reducing developing countries' dependence on fossil fuels, as was expected, ECAs appear to be investing heavily in long-term consumption and, ultimately, the associated GHG emissions. Some reasons for this could be:

- lack of policy coherence, in the sense that in most industrialized countries trade and finance policies are set apart from environmental and development assistance policies. Trade and finance ministries, including the majority of ECAs that operate in their arenas, therefore argue that addressing environmental issues, human rights or equitable development concerns lies outside their defined competencies;
- no transparency (regarding sharing of environmental information) in ECA decision-making;
- no credible environmental guidelines.

It is not that the above mentioned problems cannot be overcome. What is needed, however, is that a reform agenda for ECAs be specified, with a focus on aligning ECA activities with the climate commitments of both industrialized and developing countries. Developing countries that depend on industrialized countries for capital and technology access need to be directed towards an energy-efficient path. This is where ratification of the Kyoto Protocol and, along with it, flexibility mechanisms such as CDM become important. Their ratification would automatically lead to technologies and funds being channeled in the right direction.

Conclusion

Energy efficiency involves efficient use of resources, which is a key to sustainable development. Companies not only control emissions, but also enhance profits, when they reduce their use of energy and materials. They save the direct costs of these resources, as well as reducing disposal costs. In addition, resource efficiency often enhances productivity, streamlines production and improves workplace conditions. Companies come out ahead through helping the environment, their employees and their bottom line.

Some people believe that adopting an environment-friendly approach puts domestic private producers at a disadvantage compared with foreign competitors that follow less rigorous environmental business standards. However, the cases cited highlight the point that despite a number of problems faced by developing countries, some sectors within these countries have performed well. This is reason enough for other sectors to follow suit, and to reap the benefits of green business where energy efficiency will be the key.

This article was written with input from Jyoti Bhatia and Raaj Tiagi executives at the Confederation of Indian Industry.

Table 4
Technology changes at three Indian cement plants

	Technology change	Annual savings	Other effects
Study 1: raw meal grinding stage	• installation of high-efficiency dynamic separator for raw mill	Rs.5.4 million	• 30-35% lower energy consumption
Study 2: pyro-processing stage	• installation of low primary air burner in place of existing conventional burners	Rs. 3.2 million	• reduction of thermal energy consumption (7 kCal/kg clinker) • marginal reduction of amount of cooler vent air • sharper and shorter flame
Study 3: pyro-processing stage	• replacement of existing cooler I grate with high-efficiency cooler system	Rs. 12.0 million	• less cooler air • lower cooler exhaust and clinker temperature • compact – hence less radiation losses • thermal energy saving (30-40 kcal/kg clinker)

($1 = approx. Rs. 44)
Source: Energy conservation case study booklet, CII

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Developing the capacity to reduce environmental impacts of energy consumption: energy efficiency's role in cleaner production

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Summary

Energy efficiency and pollution reduction activities in industry began to be initiated in the 1970s. However, these activities were usually undertaken independently of one other. The need for rational energy use, as well as for a preventive approach to reduce pollution, have led to the development and promotion of cleaner production. Ways to integrate cleaner production capacity-building approaches into professional training courses and academic curricula are discussed.

Résumé

Les premières activités visant l'amélioration du rendement énergétique et la réduction de la pollution, qui remontent aux années 1970, prenaient généralement la forme d'actions isolées. La nécessité d'une utilisation rationnelle de l'énergie et d'une démarche préventive de réduction de la pollution est à l'origine du concept de production plus propre et de sa mise en œuvre. L'article examine des formules possibles pour intégrer des méthodes de renforcement des capacités à produire plus propre dans la formation professionnelle et les cursus universitaires.

Resumen

Las actividades orientadas a reducir la contaminación y ahorrar energía en la industria comenzaron en la década de 1970-80. Sin embargo, dichas actividades se emprendieron, por lo general, sin coordinación mutua. La necesidad de usar más racionalmente la energía, así como de aplicar un enfoque preventivo que permita reducir la contaminación, han propiciado el desarrollo y la promoción de métodos productivos más limpios. Este texto examina las maneras de integrar los enfoques orientados a reforzar la capacidad de descontaminar la producción, en el marco de los cursos de formación profesional y los currículos académicos.

This article focuses on approaches to capacity development in regard to cleaner production and, more specifically, on ways to incorporate energy efficiency concepts in CP techniques. Ways that CP capacity-building approaches can be integrated into professional training and academic curricula are proposed.

Between 1988 and 1998, the world's total primary energy consumption increased by an average of 11%. In the Asia Pacific region, it increased by about 47% (**Table 1**), due mainly to the shift from traditional agricultural to industrial production in this region. The rate of GDP growth in many Asian economies, despite the 1997-98 economic crisis, has shown a continuous increase (**Figure 1**). The economic crisis actually stimulated industrial growth, as countries restructured their economic policies to attract more industrial and infrastructure investment. As a result of economic liberalization, significant foreign capital has been invested in the industrial sector. At the same time, there has been an increase in incentives for modernization and the procurement of new and clean technologies. In Thailand, as part of the Japanese Government-funded Miyazawa Plan, an impressive economic restructuring plan has been proposed by the Ministry of Industries. This plan focuses on promoting cleaner production concepts as a way to improve the competitiveness of Thailand's industrial sector.

Global industrial growth in recent years has resulted in higher energy consumption and contributed to global anthropogenic emissions of CO_2 and other greenhouse gases. In 1990, industrial growth accounted for approximately 35% of global economic activity, while consuming 44% of all primary energy and emitting a similar percentage of CO_2. The International Energy Agency (IEA) data presented in **Figure 2** show that there was steady annual growth in total energy consumption by the manufacturing sector in the Asia Pacific region between 1987 and 1997. China experienced only moderate growth (1.3%) compared to that of India (6.8%). Southeast Asian countries experienced growth of 15% or more during this period.

Industry will continue to be the major source of GHG emissions. The long atmospheric residence time of these gases, their chemical properties, and ever-increasing energy demands now threaten the world's climate. By the end of 1999, atmospheric CO_2 had increased by 31% compared with the pre-industrial period. It is currently 367 ppmv (parts per million volume) (Obasi 2000). Use of outdated and inefficient production technologies in developing countries will result in continuing increases in GHG emissions.

In the 1970s and early 1980s, energy and pollution were usually treated as separate issues. Increased oil prices, the development of renewable energy resources and technologies, and promotion of energy efficient technologies were the concern of energy specialists, while pollution generation and disposal were tackled by environmental engineers. Environmental pollution was generally addressed initially by diluting pollutants, and later through control and prevention methods. These are solutions to existing problems, while cleaner production promotes prevention. The CP approach includes conservation of raw materials and energy, elimination of toxic raw materials, and reduction of the quantity and toxicity of all emissions and wastes before they leave a process. In the case of products, cleaner production helps reduce impacts along the entire life cycle from raw material extraction to disposal.

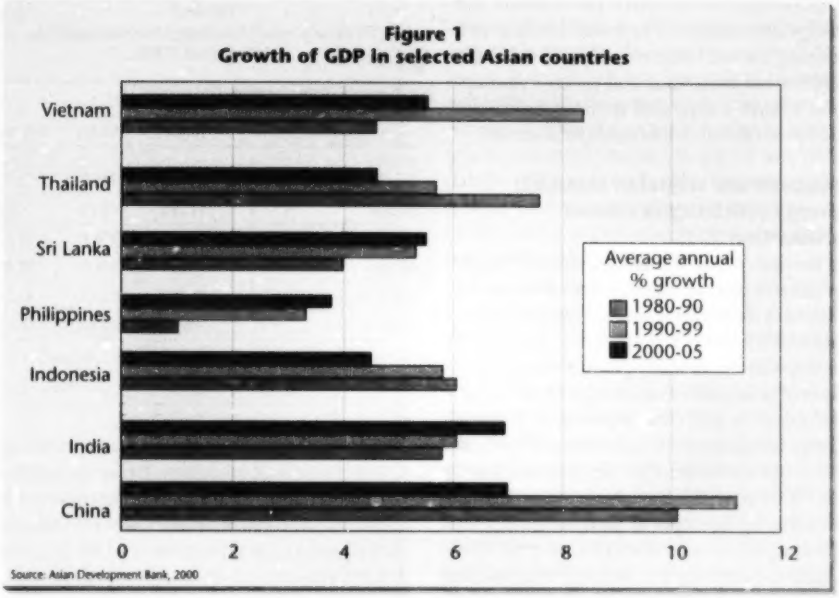
The CP approach seems obvious, but its implementation by industry only began in the early 1980s. In response to increased environmental pollution problems, industry has carried out many CP initiatives. There are a number of case studies demonstrating their benefits. CP concepts have therefore become the cornerstone of industrial pollution management in many countries. For example, in 1998 India introduced a new policy on cleaner production which all highly polluting industries are to follow. Similar policies have been introduced by Thailand, China and Sri Lanka. Unlike environmental regulations that aim to enforce compliance, the cleaner production programmes are voluntary.

Barriers to implementing cleaner production are attitudinal (i.e. poor housekeeping, resistance

to change), systematic (lack of professional management skills, inadequate quality), organizational (decision-making by only a few parties, overemphasis on production), technical (personnel's limited technical know-how, technological limitations), economic (incentives favouring production, the high cost of efficient technologies) and governmental (inadequate policies, difficulties with enforcement, environmental guidelines). Visvanathan and Kumar (1999) have listed the following factors that affect the promotion of CP in small and medium-sized industries. These factors are relevant to other sectors as well:

- integrated pollution prevention and control;
- interrelationships of energy and environment;
- use of benchmarks or standards;
- use of internal and external actors;
- capacity-building;
- technology transfer and know-how; and
- financial measures and incentives.

Figure 1
Growth of GDP in selected Asian countries



Source: Asian Development Bank, 2000

Two schools of thought: cleaner production and energy efficiency

A traditional cleaner production programme begins with a waste audit of the production facility. It identifies areas or processes where simple intervention techniques could reduce waste, improve productively and save costs. In general, CP audits are carried out to address environmental problems. They are often conducted by environmental managers. Audit programmes are the initial step in developing Environmental Management Systems (EMS) and obtaining ISO 14000 certification. The importance of CP could be measured by the interest of a region's industrial sector in obtaining the ISO 14000 standards for manufacturing. As trade liberalizes, industries in the Asia Pacific region will need ISO 14001 certification to succeed in international markets.

Energy efficiency deals with the efficient conversion and use of energy. It is a measure of the productivity provided per unit of energy consumed. Considering the potential for improvement and the direct financial gains, industries are easily persuaded to conduct energy audits as part of their management strategy. An audit is essential to implementing a more efficient process. Energy audit programmes estimate the energy consumption and efficiency of energy conversion by each piece of equipment in use and outline areas for intervention. Audits are carried out by industrial energy managers or mechanical engineers. The focus is generally on energy conservation rather than on concern about the environment. Many countries now require large industries to perform an energy audit before implementing energy conservation projects, and energy audits have become an accepted management practice in many sectors.

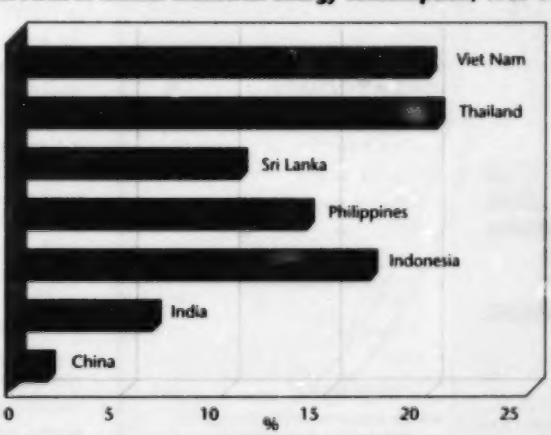
Improving energy efficiency increases productivity, significantly reduces the level of air pollutants such as CO_2, CH_4 and N_2O that contribute to GHG emissions, and reduces acid rain, solid waste production and thermal pollution. In industrialized countries, the energy efficiency of equipment such as boilers and processes such as steel and nitrogenous fertilizer production are in the order of 70-80%, 50-60% and 50%, respectively. In developing countries, comparative efficiencies are in the order of 55%, 28% and 25%. These low values are due mainly to the use of relatively less efficient production technologies. Energy consumption also depends on the type and nature of the technology used in a production process. **Figure 3** presents a technology trajectory showing increasing energy efficiency in a tea drying process. While the energy efficiency of dryers has improved over the last decade, less efficient technologies continue to be used. Many countries have laws and other measures to promote energy efficiency in various sectors. The banking sector in some countries is assisting this effort by providing soft loans. Energy efficiency is also being promoted by various external actors.

CP audits have tended to concentrate on reduction of waste water, solid waste and air emissions while neglecting energy issues. **Figure 4** shows that there is a direct interrelation between improving energy efficiency and reducing environmental pollution. It would be useful, therefore, to integrate the two in order to maximize their benefits. For example, the estimation of boiler efficiency by measuring flue gas composition for a particular fuel could also be used to calculate CO_2 emissions.

In addition to technical issues, there are territorial issues of environment versus energy. For example, utility agencies are generally responsible generating and distributing power. Most current energy conservation laws do not enforce regulations concerning high energy consumption, except perhaps through fining defaulters. Environmental regulators can only prosecute industries that do not meet emission standards. They cannot prosecute for high energy consumption. Similarly, environmental regulations are based on effluent or emission standards that deal with end-of-pipe or pollution control technologies. These standards do not require an industry to operate more efficiently in terms of the amount of pollution generated or to adopt cleaner production technologies. Different professions with two distinctly different objectives conduct energy and environmental audits. A brief report on the results of CP audits that consider both pollution and energy is presented below.

Between 1994 and 1999, under *UNEP's Network for Industrial Environmental Management (NIEM)*, 52 pulp and paper mills in the Asia Pacific region undertook CP assessments and implemented over 1000 CP recommendations, contributing to a 10-40% reduction of pollution load and a

Figure 2
Growth in annual industrial energy consumption, 1987-97



Source: International Energy Agency, *Energy Statistic of Non-OECD Countries 1996-1997*

5-20% reduction of water, raw material and energy consumption. The resource package and training manual integrate pollution reduction and raw material, water and energy consumption. However, successful applications like this are not so evident in other industrial sectors.

Towards one school of thought: energy efficiency in cleaner production

In the post-World War II era, industry thought in terms of product quantity management and little was done about quality improvement. Industries had big local markets, and virtual monopolies in particular product technologies ensured good profit margins regardless of quality. Industries paid little attention to excessive energy consumption or industrial pollution, and dilution was considered an adequate solution. By the 1960s, Japanese and German industries began introducing concepts of product quality that spread rapidly to other developed countries. Globalization of markets, free trade and multinational companies have further strengthened this concept, and technologies are quickly traded or transferred.

Along with the concept of product quality management, industries began looking at better quality products and higher production capacities. However, in the process they started damaging the environment in terms of emissions, toxic waste water, hazardous solid wastes and high energy consumption. Up until the energy crisis of the 1970s, the issue of energy consumption was not of interest to many industrial managers. The increase in energy bills sparked greater interest in energy conservation and demand side management, especially from the utility sector.

In an effort to help reduce the growing levels of pollution generated by industry, many national governments began to introduce control regulations in the early 1980s whereby industries were expected to treat waste prior to discharge to the natural environment. Initially, these end-of-pipe laws focused on waste water discharge standards rather than on air emissions. Pollution control technologies such as effluent treatment plants, wet scrubbers and filters were essentially add-ons and were considered dead investments. This view was not entirely unfounded, as these technologies merely changed the phase of the pollutants rather than eliminating them. Because they involve significant construction work, civil engineers took an early lead in developing environmental engineering curriculum.

By the early 1990s, it was becoming clear that quantity and quality of waste and the amount of energy consumed were as important as the products themselves and should be minimized to mitigate adverse environmental impacts. Environment professionals started to introduce waste minimization and cleaner production concepts to reduce the treatment charges attached to discharges. Because pollution prevention requires a sound understanding of industrial unit processes, chemical engineers got involved in environmental activities. Along with energy audits, industries started conducting environmental audits to identify potential pollution prevention options.

As a follow-up to these energy and environmental audit programmes, many national governments started developing energy and environmental labelling programmes. Labelling programmes are considered benchmarks for many industrial processes and consumer products. This has led to the concept of total quality management or preventive environmental management, which involves all these considerations in industrial production. Beyond this lies the domain of a holistic, integrated management system embodied in ISO's 14000 standard series and the idea of sustainable development which incorporates all aspects of environment and production. **Figure 5** depicts energy and environmental approaches geared towards the goal of cleaner production.

Table 1
Primary world energy consumption, 1988 and 1998

Region	Primary energy consumption	1988 (mtoe)	1998 (mtoe)	% increase
America (North, Central and South)		2462.3	2852	15.8
Europe		1755.9	1787.4	1.8
Middle East		235.6	366.7	55.6
Africa		205	261.9	27.8
Asia Pacific		1576.3	2312.7	46.7
World		7613	8477.4	11.4

mote = millions tonnes of oil equivalent

Source: BP Amoco, 1999

Capacity-building in cleaner production

Capacity-building through short-term professional training programmes and formal graduate level education can help overcome barriers related to lack of technical know-how and housekeeping, as well as lack of research capacities for developing and promoting energy efficient and environmentally sound technologies.

How a barrier is addressed depends on the target group, such as:

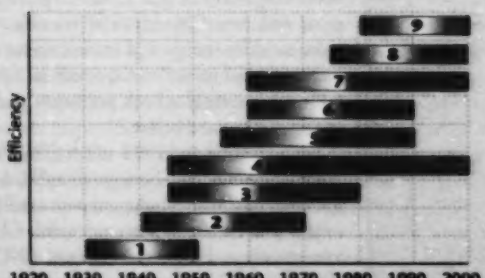
- senior executives and middle level managers in industries;
- government officials, utilities and the banking sector;
- university teachers and non-governmental organizations; and
- future engineers and managers in the industrial sector.

Professional capacity-building programmes are conducted by international and regional organizations and educational institutions, such as UNEP's NIEM, National Cleaner Production Centres (NCPCs) and the International Centre for Environmental Technology Transfer (ICETT). Programmes are tailored to specific groups of industries or related organizations. For example, as part of NIEM activities in the Asia Pacific, more than 2000 people from industry, government, industry associations and research organizations have been trained in CP. Under the ASEAN Environmental Improvement Project (EIP), more than 1000 professionals including senior executives, consultants, academics and production managers have been trained in sessions lasting from a half to two days (Hammer 1999). These short-term specific programmes incorporate energy and pollution in a holistic manner. They are targeted at selected industry professionals who usually have only undergraduate education in chemical, production or mechanical engineering.

Initiation of networks and regional programmes helps people share information, improves research capabilities, and promotes technology transfer. There can be networks for specific industrial sectors or broad groups. For example, preparation of benchmarks for industrial processes or product quality could result in better or cleaner products.

Figure 3
Technology development trajectory of tea drying

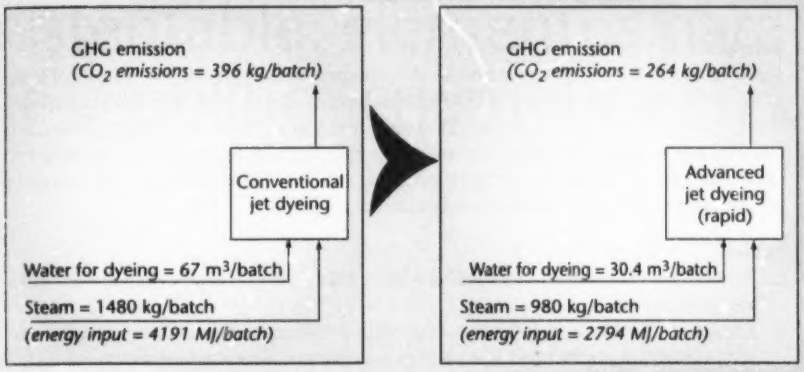
In tea processing, drying (firing) is the most energy-consuming operation. It requires about 4.5 kWh/kg of made tea (thermal energy), depending on the type of dryer used, the state of withering, the moisture content of the air, and the type of tea produced. The technology development trajectory of the tea dryer, from 1930 to the present, shows a 40% improvement in energy efficiency.



Dryer type and efficiency		%
1	Static tray	< 20.0
2	2-stage dryer	21.3
3	Four-foot tray dryer	26.8
4	Endless chain pressure (ECP) dryer	32.0
5	Fluidized bed dryer (FBD)	38.5
6	Vibratory fluidized bed dryer (VFBD)[a]	38.9
7	FBD modified	49.0
8	VFBD[b]	54.0
9	Combined tempest	> 60.0

Note: a,b: there are two different brands of VFBD.

Figure 4
Energy efficiency improvement and pollution reduction


GHG emission
(CO_2 emissions = 396 kg/batch)
Conventional jet dyeing
Water for dyeing = 67 m³/batch
Steam = 1480 kg/batch
(energy input = 4191 MJ/batch)
GHG emission
(CO_2 emissions = 264 kg/batch)
Advanced jet dyeing (rapid)
Water for dyeing = 30.4 m³/batch
Steam = 980 kg/batch
(energy input = 2794 MJ/batch)

Traditionally, the simple "jet dyeing" machines used in textile wet processing units require 1480 kg/batch, which contributes about 396 tonnes of CO_2 per batch of production. As part of their energy efficiency improvement programme, textile industries recently introduced "advanced jet dyeing" units that consume only 980 kg steam per batch. This led not only to reducing energy consumption, but also to reducing GHG emissions or the generation of air pollutants by 33% (CO_2 emissions = 264 tonnes per batch). In addition, as part of this process modification, the new continuous jet dyeing operation led to a 55% reduction of water consumption, with further significant reductions of waste water quantity and improvement of its quality. This system was developed with the objective of improving energy efficiency. It also contributes significantly to reducing environmental pollution by reducing water consumption in the dyeing operation.

Integrating cleaner production capacity-building approaches into professional training courses and academic curricula

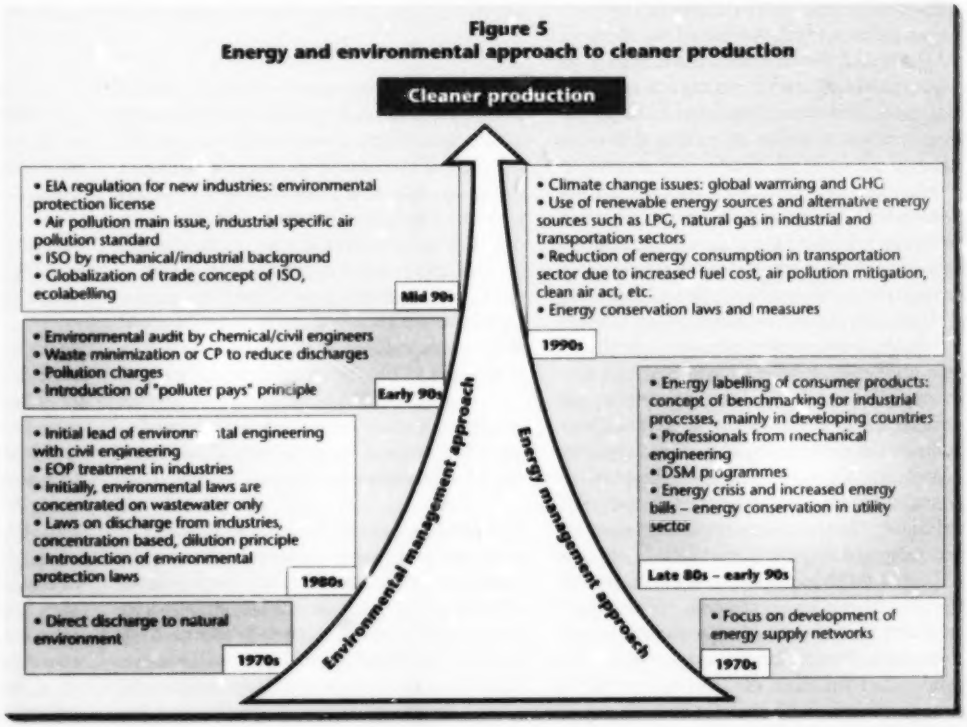
Formal graduate level programmes in environmental engineering or environmental science are offered by universities. These traditional graduate programmes have developed curricula based on end-of-pipe systems. In waste water treatment, most courses address major environmental impacts as well as various types of treatment systems such as physico-chemical treatment, biological treatment and advanced treatment systems (e.g. membrane technology). All these courses train users to operate treatment systems in order to achieve required effluent standards. Solid waste management courses deal with problems related to solid waste treatment systems (separation, recycling, stabilization and incineration) and disposal methods (landfilling). Air pollution management courses deal with the causes of air pollution, monitoring and control. More recently, undergraduate programmes have been developed in which environmental considerations are expanded to include life-cycle or "cradle to grave" perspectives. Using this approach, students are exposed to environmental problems that are not carried from one part of the product's life-cycle to another (for example, from a processing company to one of the company's customers).

Energy curricula in universities responded to the energy crisis of the 1970s and early 1980s by offering courses related to renewable energy resources (e.g. solar, biomass, wind) and their use, energy conservation principles and practices in industries, buildings and processes, and energy policies, planning and economics. Training for industrial professionals and others on issues related to energy conservation has been ongoing for more than two decades. It offers energy audit methodologies to specific industrial sectors. During the late 1980s and the 1990s, the impact of energy use on global pollution and climate change was recognized and studies on the interrelation between energy and environmental issues were initiated.

As CP initiatives are implemented, it is appropriate that existing undergraduate curricula should be revised through incorporating energy efficiency, pollution reduction and prevention, eco-design and manufacturing, and environmental management concepts into existing courses. For example, courses on heat transfer, mass transfer, waste water treatment and industrial management could be appropriately revised to enable students to approach current problems confidently in their professional careers. Industries may prefer graduates with overall "environmental literacy" rather than a few specialized engineers.

At graduate levels, specialized courses on cleaner production could be offered. Such courses are currently available in Europe and Australia. They could take a multi-disciplinary approach, and CP concepts could be covered in depth. The description of an integrated course on cleaner production principles shown in **Figure 6** lists important aspects of pollution prevention and energy efficiency relevant to implementing CP options. Courses that integrate issues related to processes and products would be useful to personnel from industries, consultants, and others involved in the production process.

Figure 5
Energy and environmental approach to cleaner production


Cleaner production
• EIA regulation for new industries: environmental protection license
• Air pollution main issue, industrial specific air pollution standard
• ISO by mechanical/industrial background
• Globalization of trade concept of ISO, ecolabelling
Mid 90s
• Environmental audit by chemical/civil engineers
• Waste minimization or CP to reduce discharges
• Pollution charges
• Introduction of "polluter pays" principle
Early 90s
• Initial lead of environmental engineering with civil engineering
• EOP treatment in industries
• Initially, environmental laws are concentrated on wastewater only
• Laws on discharge from industries, concentration based, dilution principle
• Introduction of environmental protection laws
1980s
• Direct discharge to natural environment
1970s
Environmental management approach
• Climate change issues: global warming and GHG
• Use of renewable energy sources and alternative energy sources such as LPG, natural gas in industrial and transportation sectors
• Reduction of energy consumption in transportation sector due to increased fuel cost, air pollution mitigation, clean air act, etc.
• Energy conservation laws and measures
1990s
• Energy labelling of consumer products: concept of benchmarking for industrial processes, mainly in developing countries
• Professionals from mechanical engineering
• DSM programmes
• Energy crisis and increased energy bills – energy conservation in utility sector
Late 80s – early 90s
• Focus on development of energy supply networks
1970s
Energy management approach